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REPORT OF THE INTERNATIONAL ICE PATROL IN THE NORTH ATLANTIC OC--ETC(U)
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DEPARTMENT OF TRANSPORTATION

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BULLETIN NO. 60

Report of the International Ice Patrol Service in the North Atlantic Ocean

SEASON OF 1974

CG-188-29

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ABSTRACT

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Bulletin No. 60

REPORT OF THE INTERNATIONAL ICE PATROL SERVICES IN THE NORTH ATLANTIC OCEAN

Season of 1974

CG-188-29

FOREWORD

Forwarded herewith is Bulletin No. 60 of the International Ice Patrol describing the Patrol's services, and ice observations and conditions during the 1974 season.

W. C. VENZKE
Chief, Office of Operation

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PREFACE

This report is 60th in a series of annual reports on the International Ice Patrol Service in the North Atlantic Ocean. It contains information on Ice Patrol organization, communications and operations, on ice and environmental conditions and their relationship in 1974, on oceanographic conditions, Ice Patrol research and development, and evaluation of the Airborne Radiation Thermometer and Earth Resources Technology Satellite.

The authors of this report, Commander Albert D. SUPER, USCG and Lieutenant Douglas W. CROWELL, USCG acknowledge ice and weather data provided by the Canadian Department of the Environment, weather and oceanographic data provided by the U.S. Naval Weather Service, and oceanographic data provided by the U.S. Coast Guard Oceanographic Unit. Acknowledgement is also made to Yeoman Third Class Terry L. GEST, USCG, Marine Science Technican First Class Neil O. TIBAYAN, USCG, Marine Science Technician Second Class Raymond J. EVERS, USCG, Marine Science Technician Second Class Raymond M. LARKIN, USCG, Marine Science Technician Second Class Robert N. HILDEBRAND, USCG, Marine Science Technician Third Class Paul A. LeBRUN, USCG, Marine Science Technician Third Class James M. GAYNOR, USCG, and Marine Science Technician Third Class Robert E. BLOHME, USCG, for illustrations for this report. A special acknowledgement is made to Lieutenant Junior Grade Stephen R. OSMER, USCG, who is responsible for most of the appendices to this report.

INTERNATIONAL ICE PATROL, 1974

The 1974 International Ice Service in the North Atlantic Ocean was conducted by the United States Coast Guard under the provisions of Title 46, United States Code, Section 738, 738a through 738d, and the International Convention for the Safety of Life at Sea, 1960, Regulations 5 through 8. The International Ice Patrol is a service for observing and disseminating information on ice conditions in the Grand Banks Region of the Northwest Atlantic Ocean. During the ice season, the southern and southwestern limits of the regions of icebergs in the vicinity of the Grand Banks of Newfoundland are guarded for the purpose of informing passing ships of the extent of this dangerous region. The International Ice Patrol also studies ice conditions in general, with emphasis on the formation, drift and deterioration of iceberges, and assists ships and personnel requiring aid within the limits of operation of the Ice Patrol forces.

The International Ice Patrol is directed from the Ice Patrol Office located on Governors Island, New York. The Ice Patrol Office gathers ice and environmental data from various sources, maintains an ice plot, forecasts ice conditions, prepares the twice-daily Ice Bulletin, replies to requests for special ice information, and executes operational control of the Aerial Ice Reconnaissance Detachment, the Ice Patrol Oceanographic cutter and the Surface Patrol cutter when assigned.

Vice Admiral Benjamin F. ENGEL, U.S. Coast Guard, was Commander, International Ice Patrol until July 1, 1974. After this date Vice Admiral William F. REA III, U.S. Coast Guard held this responsibility. Commander Albert D. SUPER, U.S. Coast Guard, was directly responsible for the management of the Patrol during the entire season.

Preseason flights were made in January, February and March, 1974. The Aerial Ice Reconnaissance Detachment was deployed to St. John's, Newfoundland on March 25 and returned to the United States on July 30, 1974. Several reconnaissance fiights of opportunity were conducted in August in conjunction with other missions to determine final melt of bergs and season termination. This was the first time Ice Patrol utilized St. John's for its base of operations almost exclusively. Although the cost of both accommodations and aircraft fuel were higher then previous years' operations from Canadian Forces Base Summerside, Prince Edward Island, the reduced aircraft enroute time to the vicinity of the reconnaissance area resulted in a reduction in the amount of fuel required by the aircraft. Effective search duration on-scene was also enhanced.

The 1974 Ice Season officially commenced at 0000 GMT, March 21, when the first Ice Bulletin was issued, and continued until the final Bulletin was issued at 1200 GMT, August 13, 1974. The twice-daily Ice Bulletins were broadcast by the International Ice Patrol Communications Station Boston/NIK, U.S. Naval Radio Station Norfolk/NAM, Canadian Maritime Command Radio Station Mill Cove/CFH, and Canadian Coastal Radio Station St. John's/VON. A radiofacsimile ice chart was broadcast from Boston/NIK once each day . Iceberg information was also included on the regularly scheduled radiofacsimile broadcasts of Fleet Weather Central Norfolk/NFAX, CANMARCOM/CFH, Radio Bracknell/GFE, Radio Hamburg/DGC and Radio Pinneburg/DGN.

The U.S. Coast Guard Cutter EVERGREEN, commanded by Commander Martin J. MOYNIHAN, U.S. Coast Guard, conducted oceanographic and research cruises for the Ice Patrol from April 4 to May 9, and from June 4 to July 9. During these cruises, EVERGREEN occupied oceanographic stations along select Ice Patrol standard sections, made iceberg tagging and drift observations, took anchored current meter stations and evaluated expendable surface current probes. Approximately two days of the second cruise were devoted to iceberg reconnaissance for the southernmost bergs while enroute to her home port. With the iceberg concentrations south of 46° N relatively sparce, a Surface Patrol was not required this year.

During the 1974 Season an estimated 1386 icebergs drifted south of 48° N, the second heaviest season in Ice Patrol history.

AERIAL ICE RECONNAISSANCE

During the period September 1, 1973 to August 31, 1974 a total of 79 ice observation flights were flown. Preseason flights made in January, February and March accounted for 16 flights, and the remaining 63 flights were made during the ice season. The purpose of the preseason surveys was to study iceberg distribution patterns along the Labrador coast, off Baffin Island and in the Davis Strait and to evaluate the commencement and potentail of the developing ice season. The purpose of the regular season flights was to guard the southwestern, southern and southeastern limits of icebergs, to evaluate the short-term iceberg potential of the waters immediately north of the Grand Banks, and occasionally to study the iceberg distribution along the Labrador coast. The flight statistics shown in Table 1 do not include the flight time required to make the passages between U.S. Coast Guard Air Station, Elizabeth City, North Carolina and St. John's, Newfoundland for crew relief and aircraft maintenance.

Aerial ice reconnaissance was accomplished by U.S. Coast Guard HC-130B (Lockheed Hercules) four-engine aircraft from the Coast Guard Air Station at Elizabeth City, North Carolina. During the iceberg season, the aircraft operated out of Torbay Airport, St. John's, Newfoundland almost exclusively.

On March 25, the Ice Reconnaissance Detachment deployed to St. John's from Elizabeth City. The main base remained at St. John's until July 30, when the Detachment returned to the United States.

TABLE 1.—Aerial Ice Reconnaissance Statistics
SEPTEMBER 1973 TO AUGUST 1974

Month	*Number of Flights*	*Flight Hours*
PRESEASON		
September—December	0	0
January	6	31.2
February	6	35.2
March	4	27.0
Preseason Total	16	93.4
REGULAR SEASON		
March	2	11.5
April	10	61.8
May	15	78.9
June	15	70.0
July	19	106.3
August	2	11.6
Regular Season Total	63	340.1
Annual Total	79	433.5

COMMUNICATIONS

Ice Patrol communications included receiving reports of ice and environmental conditions, transmitting Ice Bulletins and a daily facsimile chart, and the administrative and operational traffic necessary to the conduct of the Patrol. The Ice Bulletins were sent by teletype from the Third Coast Guard District Communications Center in New York to over 30 addressees, including those radio stations broadcasting the Bulletin. These stations were the U.S. Coast Guard Communications Station Boston/NIK/NMF, U.S. Naval Radio Station Norfolk/NAM, Canadian Coastal Radio Station St. John's/VON and Canadian Forces Maritime Command Radio Station Mill Cove/CFH.

Coast Guard Communications Station Boston transmitted the Ice Bulletin by CW at 0018 GMT on 5230 and 8502 kHz and at 1218 GMT on 8502 and 12750 kHz. After a 2-minute series of test signals the transmissions were made at 25 words per minute and then repeated at 15 words per minute. Coast Guard Communications Station Boston/NIK also transmitted a daily radiofacsimile broadcast depicting the locations of icebergs and sea ice at 1600 GMT simultaneously on 8502 and 12750 kHz at a drum speed of 120 revolutions per minute.

Ice Bulletins were also broadcast twice daily by U.S. Naval Radio Station Norfolk/NAM at 0430 and 1700 GMT on 88.0 (except the Tuesday 1700 GMT transmission was made on 134.9 kHz), 5870, 8090, 12135, 16180, 20225 (1700 GMT only) and 25590 (1200 GMT only) kHz; Canadian Maritime Command Radio Station Mill Cove/CFH at 0130 and 1330 GMT on 438 (except the 1330 GMT transmission the second Thursday each month), 4356.5, 6449.5, 8662, 12984, 17218.4 and 22587 (on request) kHz; and Canadian Coastal Radio Station St. John's/VON at 0000 and 1330 GMT on 478 kHz.

Radiofacsimile broadcasts that included the limits of icebergs were also made by Fleet Weather Central Norfolk/NFAX at 0320 and 1520 GMT on 4957, 8080, 10865, 16410 and 20015 kHz; Canadian Maritime Command Radio Mill Cove/CFH at 0000 and 1200 GMT on 133.15, 4271, *9890, 13510 and 17560 kHz*; Radio Bracknell/GFE at 1400 GMT on 4782, 9203, 14436 and 18261 kHz; and Radio Hamburg/DGC and Pinneburg/DGN at 0905 and 2145 GMT on 3695.3 and 13627.1 kHz, all at drum speed 120.

Special broadcasts were made by Canadian Coastal Radio Station St. John's/VON as required when icebergs were sighted outside the limits of ice between regularly scheduled broadcasts. These transmissions were preceded by the International Safety Signal (TTT) on 500 kHz.

Merchant ships calling to transmit ice sightings, weather and sea surface temperatures were requested to use the regularly assigned international call signs of the Coast Guard Ocean Stations, East Coast AMVER Radio Stations, or Canadian Coastal Radio Station St. John's/VON. All Coast Guard Stations were alert to answer NIK/NIDK calls, if used.

Ice information services for the Gulf of St. Lawrence, as well as the approaches and coastal waters of Newfoundland and Labrador, were provided by the Canadian Ministry of Transport from December until approximately late June. Ships obtained ice information by contacting the Ice Operations Officer, Dartmouth, Nova Scotia *via Sydney Marine* Radio/VCO or Halifax Marine Radio/VCS.

Communications statistics for the period September 1, 1973 through August 31, 1974 are shown in Table 2.

TABLE 2—COMMUNICATIONS STATISTICS

Number of ice reports received from ships	540
Number of ships furnishing ice reports	178
Number of ice reports received from commerical aircraft	4
Number of sea surface temperature reports	919
Number of ships furnishing sea surface temperature reports	59
Number of ships requesting special ice information	77
Number of NIK Ice Bulletins issued	292
Number of NIK facsimile broadcasts	146

There were twelve outstanding contributors of iceberg sighting reports and special sea surface temperature observations to the Ice Patrol. These ships were:

USCGC HAMILTON/NMAG
M/V ATLANTIC SPAN/SLPN
M/V BAKAR/LFSW
USCGC CHASE/NLPM
M/V BANIJA/YTEK
M/V BENEDETTA F/ICIB
USCGC MORGENTHAU/NDWA
M/V BOCKENHELM/DDNQ
M/V LIVANITA/JXRN
USCGC EDISTO/NIQU
USCGC WESTWIND/NLKL
M/V MANCHESTER ZEAL/GSED

ICE CONDITIONS, 1974 SEASON

September—December 1973

After the close of the 1973 Ice Patrol Season, occasional icebergs continued to drift south along the Labrador coast. In September only one iceberg report was received, that of a small berg in the Strait of Belle Isle. Sea ice conditions were normal over Baffin Bay and Davis Strait with freeze-up starting in the extreme north of Baffin Bay during the third and fourth weeks of September. In October and November, there were numerous reports of icebergs in the Strait of Belle Isle, its approaches, and northward to Hamilton Inlet. The southernmost of these was a small berg at 50° 48′N 57° 47′W at the Strait's western approach. The sea ice developed very slowly during October, but by the end of November, it had slightly exceeded its normal limits in Baffin Bay. There were no iceberg reports received in December. The slight excess of sea ice was maintained in Baffin Bay while the ice formation off the Labrador coast progressed slower than normal.

January 1974

There were no icebergs reported to the Ice Patrol office by maritime traffic in January. During the first week, new and grey ice formed south of 51°N, extending into Notre Dame Bay with some drifting around Cape Freels to near 49°N. The heavier Labrador pack ice advanced to 52°N. A preseason survey was conducted January 6–15 along the Labrador and Baffin Island coasts and across Davis Strait. The flight tracks and observed icebergs are shown in figure 1. Only a few icebergs were observed south of 56°N, about normal concentrations from 56°N to Cape Chidley, Labrador, and much above normal concentrations along the Baffin Island coast to north of Cape Dyer and across Davis Strait. Of significance were two icebergs (a small and a medium) just off the Newfoundland coast near Cape Freels. This was the first time the Baffin Island coast from Cape Dyer to Cape Christian was investigated as part of the January preseason survey. The latitudinal distribution of icebergs is illustrated graphically in Figure 2. By the end of January a large excess of sea ice developed over the Davis Strait and off Labrador and Newfoundland. New and grey ice had progressed as far south as 47° 30′N and as far east as 49° 18′W. Open water remained along the Avalon Peninsula to Cape Bonavista, but generally close pack new and grey ice lay in the coastal approaches to Notre Dame Bay.

February 1974

During the first half of February only two icebergs were reported, both over 400 miles off the coast of Labrador. There was a rapid south-southeastward spread of pack ice off Newfoundland so that by mid-month it extended as far south as 46° 10′N 52° 30′W and as far east as 47°W. The extent of pack ice returned to normal over Davis Strait and along the coast of Labrador. Offshore drift prevented any significant intrusions into east Newfoundland coastal areas. In eastern Notre Dame Bay very close pack white and grey-white ice developed, while lighter conditions were the rule for the western sections of the Bay. This month's preseason survey, conducted February 19 through March 1, revealed three times the usual iceberg population south of Cape Chidley, Labrador. This was also the first time the southern Baffin Island coast and Davis Strait were surveyed during February. A total of 2403 icebergs were located from the Davis Strait southward. The flight tracks and iceberg concentrations are shown in figure 3 with the latitudinal berg distribution displayed graphically in figure 4. The sea ice edge retreated rapidly during the last two weeks of February so that by the end of the month the southern limit was lying east of St. John's with a tongue of light sea ice extending eastward over the northern Grand Banks. The computer drift of a medium iceberg reported in position 48° 28′N 46° 28′W on February 24 had it south of 48°N by the end of the month, the first iceberg of the season.

March 1974

With no additional icebergs reported to the Ice Patrol office in early March, an additional preason survey was conducted March 12–15. The flight tracks and observed icebergs are shown in Figure 5. The southernmost berg during this survey was at 47°20′N 46°14′W with one additional berg south of 48°N. Twenty-nine icebergs and many growlers were sighted between 48°N and 49°N; fifty-one bergs and many growlers between 49°N and 50°N. On the basis of these flights, computer ice drifts and an analysis of actual and predicted pressure patterns, the first bergs were estimated to drift south of 46°N by March 21, thus Ice Patrol services commenced that date. Ice Patrol forces were deployed to St. John's, Newfoundland on March 25. Sea ice conditions were normal over Davis Strait during March with a slight deficit off the Labrador coast. The southern edge of the pack remained between 47°N and 48°N through mid-March. The heavier pack ice remained well offshore, and at the end of the month, the southern limit extended eastward from St. John's very similar to its position at the beginning of the month. Figure 6 shows these sea ice conditions along with the southernmost iceberg of the month at 45°36′N 43°25′W. After a good reconnaissance flight by the Ice Patrol aircraft on March 30, together with the computer drift of the preseason iceberg survey, 99 icebergs were estimated to have drifted south of 48°N during the month.

April 1974

Good reconnaissance flights on April 3 and 4 located almost 100 icebergs and over 50 growlers between 47°N and 49°N. These are shown in figure 7. During the first half of April, the approaches to St. John's remained open and the ice edge began its seasonal northward retreat. At mid-month, 421 icebergs and 111 growlers were located as shown in figure 8. The tongue of sea ice north of the Grand Banks area changed little, if any, during the rest of the month. Towards the end of April, 148 icebergs and 47 growlers were located in the vicinity of 48°N and east of Flemish Cap as shown in figure 9. The southernmost and eastermost icebergs for the month occurred on April 30 at 44°31′N 46°07′W and 46°40′N 40°17′W, respectively, as shown in figure 10. The southernmost was some 250 miles north of its position during April of last year, thus indicating a surface patrol may not be necessary. It was an extremely heavy month, however, with an estimated 345 icebergs drifting south of 48°N. The tongue of sea ice north of the Grand Banks area changed little, if any, by the end of the month. The edge of open pack ice extended as far south as 46°15′N and as far east as 47°W.

May 1974

On the first of May a good flight covering the northern Grand Banks and Flemish Cap revealed 72 icebergs and 31 growlers, then on the fourth, a flight north of this area revealed an additional 161 icebergs, 40 growlers and 115 radar targets. These are shown in figure 11. Also on May 4, the edge of sea ice reached 47°N 45°40′W. By May 10, the tongue had disappeared, leaving no sea ice south of 58°N. North of about 55°N, however, a new excess of sea ice was apparent. Flights on May 10, 12 and 13 (figure 12) revealed a total of 740 icebergs, an indication that this was not going to be just a heavy year, but one of the heaviest years in Ice Patrol history. On May 15, the easternmost iceberg of the month was at 47°52′N 37°55′W as shown in figure 13. By the end of the month, the eastern limits of sea ice had continued to decrease, however, the southern limit remained in the vicinity of Baccalieu Island. The southernmost berg of the month, as depicted with the ice conditions in figure 14, was 130 miles north of the southernmost iceberg positions during the same month last year. Thus any apprehension of requiring a surface patrol was abated. An estimated 446 icebergs drifted south of 48°N during the month.

June 1974

On the first of June, 121 icebergs and 43 growlers were located on the northern Grand Banks and Flemish Cap. Then on June 2, the area southeast of Flemish Cap was investigated, searching for icebergs previously reported by ships. The visibility was excellent, but nothing was sighted indicating that the bergs had already melted. These flights are shown in figure 15. Early in the month sea ice remained in Conception and Trinity Bays and northwest along the coast approximately 60 miles offshores. The easternmost iceberg of the season was in position 49°25′N 37°53′W on June 10. The ice condi-

tions on this date are displayed in figure 16. On June 18 a coastal and northern flight from south of the Avalon Peninsula to just south of Hamilton Inlet revealed over 800 icebergs, a very significant number for the remainder of the season. Poor on scene visibility limited the effectiveness of the remainder of the flights this month. Based on computer drift, the southernmost iceberg of the season was in position 41°24′N 48°10′W on June 25. The ice conditions on this date are shown in figure 17. An extensive belt of sea ice remained along the coasts of Labrador and Newfoundland which are normally clear by the end of June. It was estimated that 266 icebergs drifted south of 48°N during the month.

July 1974

On July 6, a coastal flight located 39 icebergs east and south of the Avalon Peninsula. On the following day a good flight covered the eastern slope of the Grand Banks revealing only 16 icebergs. These are shown in figure 18. The Strait of Belle Isle was clear of sea ice on July 12, except for patches along the northern shore. Only a few patches of sea ice remained along the northeast coast of Newfoundland, and these rapidly disappeared. Another coastal flight at mid-month revealed almost 100 icebergs northeast and east of the Avalon Peninsula. There was persistent fog on the Grand Banks for the next two weeks with all aircraft reconnaissance failing to detect anything but radar targets. Good flights were finally obtained on July 29 and 30 (figure 19) locating two small icebergs east of the Tail of the Banks with the next southernmost bergs in the vicinity of 47°N. A total of only 13 icebergs and one growler were sighted. Thus, the Ice Reconnaissance Detachment returned to New York and North Carolina on July 30. The July estimate of bergs south of 48°N was still 168, some ten times the monthly normal and brought the season count to over 1300 icebergs with one month remaining. Also, at the end of the month, over 100 icebergs were reported in the Strait of Belle Isle with over 50 bergs in its eastern approaches.

August 1974

Ship reports of the southernmost and easternmost icebergs persisted so ice observers were deployed with a Coast Guard C–130 logistics mission to Dakar, Senegal. One flight was conducted enroute St. John's on August 8, with a dedicated survey on the following day. As shown in figure 20, one iceberg and three growlers were located near the Tail of the Banks with 80 icebergs north of 47° 25′N and concentrated between 48°N and 49°N. The return flight from Dakar located the remains of two small rapidly melting pieces of ice on August 12 in positions 46° 15′N 46° 25′W and 46° 08′N 46° 53′W. These were estimated to melt completely within the next day. Thus, Ice Patrol services for the 1974 Season were terminated on August 13, with a minimal threat of icebergs south of 47°N. Many icebergs were reported during the remainder of the month in the eastern approaches to the Strait of the Belle Isle and a few just west of Flemish Cap after the season closed. It was estimated than an additional 61 icebergs drifted south of 48°N during the month of August bringing the season total to 1386, the second heaviest on record.

Table 3—ESTIMATED NUMBER OF ICEBERGS SOUTH OF LATITUDE 48 N, SEASON 1974

	Sept	Oct	Nov	Dec	Jan	Feb	May	Apr	May	Jun	Jul	Aug	Total
1974	0	0	0	0	0	1	99	345	446	266	168	61	1386
TOTAL 1946–1974	9	2	4	11	64	237	994	2916	2810	1711	480	100	9338
AVERAGE 1946–1974	0	0	0	0	2	8	34	100	97	59	17	3	322
TOTAL 1900–1974	255	109	110	91	184	688	3096	7761	9893	5229	1676	489	29,581
AVERAGE 1900–1974	3	1	1	1	2	9	41	103	132	70	22	7	394

OCEANOGRAPHIC CONDITIONS, 1974

R. W. Scoble

(U.S. COAST GUARD OCEANOGRAPHIC UNIT)

During the 1974 Ice Patrol Season, two oceanographic cruises (April 2—May 9 and June 4—July 9) were conducted in the vicinity of the Grand Banks aboard CGC EVERGREEN (WAGO–295). The primary purpose of these cruises was to provide Commander, International Ice Patrol (CIIP) with current data which could be utilized in forecasting the drift of icebergs threatening North Atlantic shipping. The secondary purpose was to conduct research projects relating to Ice Patrol. One of these projects was designed to determine how icebergs are affected by wind and ocean currents, while another project consisted of measuring deep ocean currents.

Surface currents were calculated from salinity and temperature data collected with a Salinity, Temperature, Depth Environmental Profiling System (STD). STD casts were taken along standard Ice Patrol sections to a depth of 1000 meters in deep water and to as close to the bottom as practicable in the shallower water along the continental slope. All STD data were processed real–time aboard ship using a Digital Data Logger/Computer arrangement and were subsequently transmitted to CIIP.

Dynamic topography charts were produced from STD data and are presented here. To maintain synopticity, each chart represents half of one cruise. The Labrador Current, as usual, was flowing along the eastern edge of the Grand Banks during the first part of the first cruise (figure 21). The dynamic trough east of the Labrador Current is wider than normal and very flat. The steep gradient across the North Atlantic Current can be seen in the southeast portion of the survey area.

The survey conducted during the second part of the first cruise (figure 22), was an abbreviation of the survey conducted earlier in April. It appears that no significant changes occurred to the dynamic topography between these two surveys. The counterclockwise flow, which normally appears around Flemish Cap, was located below Flemish Cap during the second survey.

By the first half of the second cruise (figure 23), the dynamic topography had returned to nearly normal conditions and the gradients in the North Atlantic Current meander were not as steep as expected. Similar conditions were also observed during the second half of the second cruise (figure 24).

Iceberg tagging and tracking experiments were conducted twice (Aril 20—24 and June 20—29) during the Ice Patrol Season. The first experiment proved to be of only limited value primarily due to severe weather conditions. The second study was more successful with six icebergs being tracked; one of these icebergs was tracked for four days and nearly 100 miles.

A deep subsurface current meter array, which had been set at 44° 42.6′U, 48° 58.0′W from CGC EDISTO (WAGB–284) on February 11, 1974, was recovered on April 8. That array was replaced the same day by a similar array which was recovered on June 12. On June 13, a third array was set at 44° 40′N, 48° 59′W. Plans have been made to recover this array during the 1975 Ice Patrol Season. All these current meters were set to test the validity of using the 1000 decibar surface as a reference level for dynamic calculations.

More complete analysis of the STD data and results of the research projects will be reported in the U.S.C.G. Oceanographic Report Series (CG 373).

DISCUSSION OF ICEBERG AND ENVIRONMENTAL CONDITIONS

1974 ICE SEASON

The 1974 Season total of 1386 icebergs south of 48°N was the second heaviest in Ice Patrol history, surpassing the 1929 count of 1329. Of almost equal historical significance is that never before had there been three very heavy years in succession, that of 1584 icebergs during the 1972 Season and 947 during 1973. In attempting to explain the severity of the 1974 Season, the environmental factors, including the number of icebergs available to drift south of 48°N, the strength and duration of the northwesterly winds that help produce southerly iceberg transport, the sea ice cover that protects the icebergs, the development of the Labrador Current features (discussed in the Oceanographic Conditions, 1974 section), and the deterioration of icebergs are analyzed in the following paragraphs.

During the January preseason flight a total of 1281 icebergs were sighted as shown in figure 1. Almost 600 of these bergs were counted by extending the survey area northward to Cape Christian, but it was still over a hundred bergs shy of the season total. Either of two suggestions are offered: the environmental conditions were extreme allowing for icebergs to drift from north of Cape Christian to south of 48°N or, East Greenland icebergs provided a more significant input to the seasonal berg total by drifting westward across the northern Labrador Sea and the Davis Strait. The February preseason survey totaled 2403 icebergs, as shown in figure 3, providing a reasonable explanation for its extremely heavy year and still allowing for berg casualties on the 1000 plus mile journey down the coast of Labrador into the Grand Banks area. In both January and February a large number of icebergs were located in the middle of the Davis Strait. As will be shown in the environmental conditions, icebergs from both north of Cape Christian and southeast of Davis Strait had the potential to move into the area between the January and February surveys.

Figures 26a through 26h show the normal and the 1974 surface pressure patterns for January through August. Because the January preseason survey revealed only three icebergs south of 56°N, those off Hamilton Inlet, it was not deemed necessary to analyze any of the prior months. The mean pressure pattern for January 1974 was dominated by the Icelandic Low, located 60°N 27°W, with a pressure of 973 mb. With the normal of almost 1000mb, a 27-mb anomoly was centered in the Low. Not only was the Icelandic Low more intense, the Azores High was higher in pressure at 1027 mb, and covered more area in the east-west direction. Thus the winds along the Baffin Island and Labrador coasts were extreme northerlies, possibly even a record, and provided for maximum iceberg southerly drift. Thus, the increased berg count in the February over the January survey can be accounted for.

The February 30–day mean pressure pattern was near normal in configuration, but the Icelandic Low, although recovering to 993 mb, was still over 10-mb lower than normal and displaced some 400 miles east of its usual position. The Azores High was normally located, but at 1025 mb it was 4 mb higher than usual. Thus, compared to January, the anomalies were small, but there was still a significant negative 9-mb anomaly off Labrador with an anomalous trough over Newfoundland. This enhanced the transport of icebergs across the Davis Strait and south along the Labrador coast.

The March mean pressure pattern was normal in appearance like February, but the central pressures were more extreme. The Icelandic Low at 993 mb was more than 12 mb deeper than usual and located 100 miles south of Kap Farvel, slightly west of its normal position. With the Azores High 5 mb higher than normal, major

departures were evident, especially over Baffin Bay and along the coast of Labrador (negative anomolies of 11 mb and 13 mb, respectively).

April brought a return to near-normal patterns and pressures with the Icelandic Low at 1003 mb only 4 mb below normal and located at its normal position southwest of Kap Farvel. The Azores High at 1025 mb was only 4 mb higher than usual and about 5° west of its normal location. Thus the winds were more northerly over the Labrador coast and about the usual magnitudes.

The May mean pressure pattern was more intensive than normal with the difference between the Icelandic Low and the Azores High more than usual. They were both in their usual positions providing for the same wind directions but larger magnitudes than normal.

In June, for the first time this year, the differences between the Icelandic Low and Azores High were less than normal. The June Icelandic Low was at its normal pressure but was relocated near 55°N 43°W rather than over the Labrador coast and had a second center over Iceland. The Azores High was in its usual position near 33°N 38°W and about 2 mb lower than normal. The departures from normal were thus small and confined to a positive 4 mb anomoly off the Labrador coast

The July Bermuda-Azores High closely resembled its usual features with the pressure pattern off the Labrador and Newfoundland coasts being mirror-images of the normal. In August the mean pressure pattern intensified with the Bermuda-Azores High 2 mb higher than normal and the 1005-mb Icelandic Low over 5 mb lower than normal. The High over the Greenland Ice Cap was 5 mb higher than normal at 1018 mb. The resulting greater than normal northwesterly winds had little effect on the rapidly closing Ice Season.

To determine and assign numerical values to the existing wind conditions, surface pressure gradients (differences in atmospheric pressure along a geographically orientated line) may be used. Six such gradients are defined in figure 27. From an analysis of these gradients, inferences can be made as to the northwesterly winds producing southerly iceberg drift, accentuating the Labrador Current, reducing the air and sea temperatures, and spreading and developing sea ice along the coasts of Labrador and Newfoundland.

Gradients 1 and 2 measure the winds of the coast of Labrador which are important in setting up the drift for transporting icebergs to the general area northeast of Newfoundland. Gradient 3 measures the wind component which assists or impedes icebergs as they drift along the eastern slope of the Grand Banks. Gradient 4 is a measure of the influence of westerly (or easterly) winds along the northern slope of the Grand Banks. This latter gradient is important in determining iceberg drift away from the Newfoundland coast and into the core of the Labrador Current. If the winds are too strong (or persistent) when the bergs reach the northeast corner of the Grand Banks, they may be carried out over Flemish Cap and into the warm waters of the North Atlantic Current. Gradients 5 and 6 provide a preseason indication of potential iceberg drift south and west in the Davis Strait, respectively.

The 1974 pressure gradient statistics are shown graphically in figure 27 in comparison with their 1946—1973 averages. Gradients 1 and 2 provide a tremendous impetus to southerly iceberg drift in January with almost three times the normal values, then after mid-February they display a continued above average value for the remainder of the season. Icebergs didn't reach the area of pressure gradients 3 and 4 until early March. From then until mid-June Gradient 3 averaged slightly negative while Gradient 4 slowly diminished from over three times its normal value to slightly above normal. These gradients clearly show very little, if any, southerly iceberg drift potential once the iceberg reached the northern Grand Banks region, and explain why that, in spite of the excessive number of bergs, a surface patrol was not required. The predominent westerly winds shown in gradient 4 kept most of the icebergs out of the influence of the main Labrador current drifting east over the Flemish Cap area and limiting only a few bergs to the region of the Tail of the Banks in June, relatively late in the season when the waters are showing major warming trends. Gradients 5 and 6 show large deviations form normal in the critical January through March time frame in the Davis Strait area. Thus extra impetus was provided to icebergs moving south through the Strait as well as westward across it.

Air temperatures along Baffin Island averaged about normal while those along the Labrador and Newfoundland coasts were much below normal throughout the winter and spring, and well into the summer months, as shown in figure 29. The locations of the stations monitored are shown in figure 27. A frost degree day, as used in figure 29, is defined as one day mean temperature of one Fahrenheit degree below 32° (e.g., one day at 20°F would be 12 frost degree days). Similarly, a melting degree day is one day mean temperature of one Fahrenheit degree above 32°. All stations had a below normal frost degree day accumulation at the end of December. By the end of January, the Newfoundland and Labrador stations had surpassed their respective normals and made rapid accumulations through the early spring. The melting degree accumulations for the remainder of spring and for the entire summer lagged significantly behind normal. Iceberg deterioration can thus be inferred to be less than normal allowing a greatly retarded mortality rate among the bergs destined for the Grand Banks, and an extension of the season of at about a month past its normal termination in mid-July.

These same environmental conditions described above produced a greater and more persistent sea ice cover as discussed in the section on Ice Conditions, 1974 Season. This provided protection to the bergs from sea state erosion through a greater portion of their journey and particularly influenced the larger counts south of 48°N latitude in the second half of the season. Collaterally, sea surface temperatures were lower than normal in the vicinity of the Grand Banks throughout the season.

RESEARCH AND DEVELOPMENT, 1974

During the spring of 1974, responsibility for International Ice Patrol research and development was transferred from the Coast Guard Oceanographic Unit, Washington, D.C. to the Coast Guard Research and Development Center, Groton, Connecticut. These tasks include iceberg detection and tracking, drift and prediction, deterioration, destruction, and production.

During the Ice Patrol cruises of USCGC EVERGREEN, an "Iceberg Tagging and Tracking Project" was conducted. The interim report by R. W. Scobie and R. M. Hayes of the Coast Guard Oceanographic Unit and R. Q. Robe of the Coast Guard Research and Development Center is included as Appendix A to this Bulletin.

Later during the summer, USCGC EDISTO conducted a "Labrador Coast Oceanographic Survey". A summary is included in this Bulletin as Appendix B. EDISTO also conducted iceberg studies in July and August 1974 in the Labrador Sea and Baffin Bay under the direction of R. Q. Robe of the Coast Guard Research and Development Center. These projects investigated the relationship of iceberg heights to drafts and total mass determinations relative to above surface dimensions. They will be reported in subsequent Ice Patrol Bulletins.

Also included in this Bulletin are evaluations of the Airborne Radiation Thermometer and the Earth Resources Technical Satellite, both by LTJG S. R. OSMER, USCG as Appendices C and D, respectively.

ICE AND SEA SURFACE TEMPERATURE REPORTS RECEIVED FROM SHIP'S OF PARTICIPATING NATIONS DURING 1974

BEGIUM

	ICE	SST
CHERTAL	1	
FEDERAL SCHELDE	1	
FINA AMERICA	1	1
FRUBEL OCEANIA	1	
MINERAL SERAING	1	1

CANADA

	ICE	SST
BAFFIN	3	
CAPE FREELS	5	
CARINO	1	
GULF CANADA	1	
IMPERIAL ACADIA	2	
KAKAWI	1	
GREAT BRITAIN	1	

DENMARK

	ICE	SST
"HOLLAND"	1	
INGE MAERSK	1	

FINLAND

	ICE	SST
GERMUNDO	1	1
GREREERSO	2	
KEPPO	1	
MALTESHOLM		3

FRANCE

	ICE	SST
ATLANTIC CHAMPAGNE	2	1
ATLANTIC COGNAC	1	
CATHERINE	3	1
CETRA LYRA	1	
FRANCE	3	1
MONT LOUIS	2	
ONDINE	1	
PENQUER	3	
ZELANDE	1	

FEDERAL REPUBLIC OF GERMANY

	ICE	SST
ALSTER EXPRESS	2	
ANA LUISA		2
BOCKENHEIM	15	
BORHEIM	3	
BRUNSBUTTEL		3
BUNTENSTEIN	2	
EBERHARDT ESSBERGER	1	
ELBE EXPRESS	4	
ERLANGEN		
FAROS	1	3
GAMMAGAS	2	
INO-A	2	1
JOHANN SCHULTE	1	
LEO SCHROEDER	1	
LEVERKUSEN	7	1
MELLUMERSAND	3	3
MOSEL EXPRESS	2	
MUENCHEN	3	
PROSERPINA	3	7
SAARLAND	1	
WESER	3	
WESER EXPRESS	1	
WESERMUNDE	1	
WIDAR	1	1
ZIM TOKYO	1	

GREAT BRITAIN

	ICE	SST
ANGLIA TEAM	1	1
ASIA GREIGHTER	1	
ATLANTIC CAUSEWAY	1	
ATLANTIC CITY	1	
AVON FOREST	1	
"BAMBURGH" CASTLE	1	
BEECHWOOD	1	
BENIHANT		3
BERNES	1	
BRIMNES	1	
CAMERONIA	1	
CAPE NELSON	1	
CAST BEAVER	6	
CHEVIOT	1	
CP AMBASSADOR	2	
CP DISCOVERER	6	
CP TRADER	2	

GREAT BRITAIN—Continued

	ICE	SST
CP VOYAGEUR	8	
DART AMERICA	2	
DART ATLANTIC	4	1
DUKESGARTH	3	
FINNAMORE MEADOW	6	
H1070	1	
IDA LUNDRIGAN	1	
KING WILLIAM	1	
LONGSTONE	1	
MANCHESTER CONCORDE	5	
MANCHESTER COURAGE	7	1
MANCHESTER CRUSADE	4	
MANCHESTER QUEST	3	1
MANCHESTER ZEAL	4	8
MONKSGARTH	2	
MORANT		1
NEWFOUNDLAND COAST	1	
OCEAN SHORE	1	
ORBITA	1	
QUEEN ELIZABETH	3	
QUEENSGARTH	4	2
TROLL PARK	3	
WILTSHIRE	1	1

GREECE

	ICE	SST
ANNOULA	1	
ANTHENIAN HORIZON	2	
ATLANTIC CHAMPION	2	
EFTYCHIA	1	
GRECIAN LIGHT	1	
IRINI	1	
LADY ERA	3	3
LIBRA	1	1
NORTH HIGHNESS		2
OCEAN MARINER	1	
POUKOU	1	

ITALY

	ICE	SST
BENEDETTA F.	8	9
ELISA F.		3

JAPAN

	ICE	SST
TOEI MARU	2	4

LIBERIA

	ICE	SST
CAPE CANAVERAL	1	
CAPETAN GIORGIS	2	2
CARLANTIC	1	
DARIEN		4
DOBERG	1	1
HARRY C. WEBB	2	
MOZART	1	1
NESTOS	1	
NEW ENGLAND HUNTER	1	
NEW ENGLAND TRAPPER	1	
OGDEN EXPORTER	5	
PANETOLIKON	1	
PENNY MICHAELS	1	

NETHERLANDS

	ICE	SST
HOLENDRECHT	2	
NEDLLOYD DELFT		8

NORWAY

	ICE	SST
AUSTANGER	1	
BAKAR		33
CANTO	1	
CARMENCITA		5
FERDALE	1	1
HAVDRILL OIL RIG	4	
IDEFJORD	3	
KRISTIN BROVIG	1	
LIANA	1	
LIVANITA	15	
MOS GULF	1	
NORSE CAPTAIN	1	8
SAGAFJORD	1	
VANESSA	2	
VISTAFJORD	2	
JOHAN E.	1	

PANAMA

	ICE	SST
CARCASTLE	1	
HELENE ROTH	1	
LINDBLAD EXPLORER	1	
MESSENGER	1	1
TRADE STAR	1	

SPAIN

	ICE	SST
ERMUA		1
MANUEL YLLERA	1	

SWEDEN

	ICE	SST
ATLANTIC SPAN	6	31
GRIPSHOLM	1	
KUNGSHOLM	4	
MONT ROYAL	4	

	ICE	SST
UNITED STATES OF AMERICA		
AMERICAN ACCORD		2
AMERICAN ALLIANCE	2	
AMERICAN LEADER	1	
USNS MAUMEE	1	
PELICAN	2	2
PRAIRIE GROVE	1	
TRANSCOLUMBIA		1
U.S. COAST GUARD		
CGC BIBB	2	
CGC CAMPBELL	4	
CGC CHASE	17	12
CGC DUANE	2	
CGC EDISTO	12	1
CGC EVERGREEN	30	704
CGC GALLATIN	1	2
CGC HAMILTON	82	
CGC MORGENTHAU	17	
CGC WESTWIND	14	
YUGOSLAVIA		
BANIJA	12	16
BARANJA	1	
IDRIJA	3	
IVO VOJNOVIC	4	

APPENDIX A

ICEBERG TAGGING AND TRACKING PROJECT 1974

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INTRODUCTION

During the 1974 Ice Patrol Season the Coast Guard Research and Development Center and the Coast Guard Oceanographic Unit conducted an iceberg drift project aboard the Coast Guard Cutter EVERGREEN. This project provided average drift vectors for six icebergs in the Grand Banks of Newfoundland area over a period of three to six days. The results were forwarded to Commander, International Ice Patrol (IIP). Comparisons could then be made by IIP between the observed drift values and those predicted by computer model. Icebergs were tagged to allow for the surveillance of a number of bergs distributed over an area of up to 300 square miles. This also assured positive identification upon subsequent visits to obtain position fixes. In the past, attempts have been made to mark icebergs using dye, however, iceberg melting, rain, wave action, and iceberg rolling often caused the dye patches to be washed away. The complications involved in tagging a berg for future recognition center around the dynamic nature of an iceberg.

Icebergs near the Grand Banks normally melt rapidly. A berg's rate of decay was a function of its environment and internal structure. Deterioration was hastened by warm sea and air temperatures, as well as by rough seas. Rivulets of melting water were seen cascading down the sides of some icebergs creating large channels on the surface and often collecting in pools in the basin areas. Others of the drydock variety had wave cut embayments which concentrated wave forces and speeded deterioration. Large chunks of ice often calved off icebergs to accelerate their destruction. Instabilities, which resulted from deterioration, caused icebergs to pitch and yaw and in severe cases to roll over completely. In consequence of these dynamic changes, it was very difficult to put anything on, or attach any device to, an iceberg that would remain in position long enough to give positive identification over a significant time interval (i.e., about 5–7 days).

METHODS

During the International Ice Patrol 1974 season a method was tested for the relocation and differentiation of icebergs used in drift studies near the Grand Bank region. The bergs were surrounded by an array of floats (styrofoam cylinders) connected by buoyant line (polypropylene, 3/8″ diameter). The length of this line varied from 400 to 800m depending upon the size of the iceberg. A spar-type, buoyant RDF transmitter was included in the line circle. One hundred and eighty degrees from the transmitter was a spar buoy with a radar reflector for electronic detection and/or red flags for visual detection (Figure A-1). Each RDF transmitter had a different transmission frequency to permit positive identification independent of visual observation. The transmitters were located with an automatic direction finder mounted on the bridge. The antenna for this system was secured to the railing just forward of the bridge. Early attempts at locating the RDF transmitters using handheld receiving sets were frustrated by the apparent omnidirectionality of the signal at ranges closer than 3700m as well as directional ambiguity at greater distances.

The tagging arrays were deployed from the CGC EVERGREEN during April and June of 1974. This was accomplished by casting off a spherical float attached to one end of the line. The line was then paid out as the vessel steamed around the iceberg. The cutter closed on the float heading into the wind and retrieved the spherical float with a grapnel. The two ends of the line, each having eye splices and thimbles, were joined together with a shackle. The tethering ring of the RDF spar buoy was attached to the shackle and placed in the water. The iceberg, thus encircled, carried along its array as it drifted.

During the first cruise (April/May 1974) the iceberg tagging project was plagued with the difficulty of locating suitable icebergs for tagging (i.e., small enough size) in the survey area. Later a storm carried away the arrays from the icebergs that finally were tagged. This storm lasted about two days with winds reaching 38 kts and the sea increased to 16 feet. All three tagging arrays were carried away and only one was recovered. The line on the recovered array was broken in two places. One break occurred with such force that the ends of the line fibers were fused; there was no evidence of chafing. The other break appeared to be the result of chafing. Because of this, little useful drift data were obtained from the first cruise.

The second cruise, using similar arrays, met with greater success because of more favorable weather. The CGC EVERGREEN was able to track several icebergs in dense fog for nine days. However, the tagging arrays slipped repeatedly over or under the icebergs. This necessitated early recovery of the equipment, which drifted away from the berg although the line circle had remained intact. This result was completely unexpected and probably resulted from the iceberg snagging the line and rolling out of the loop.

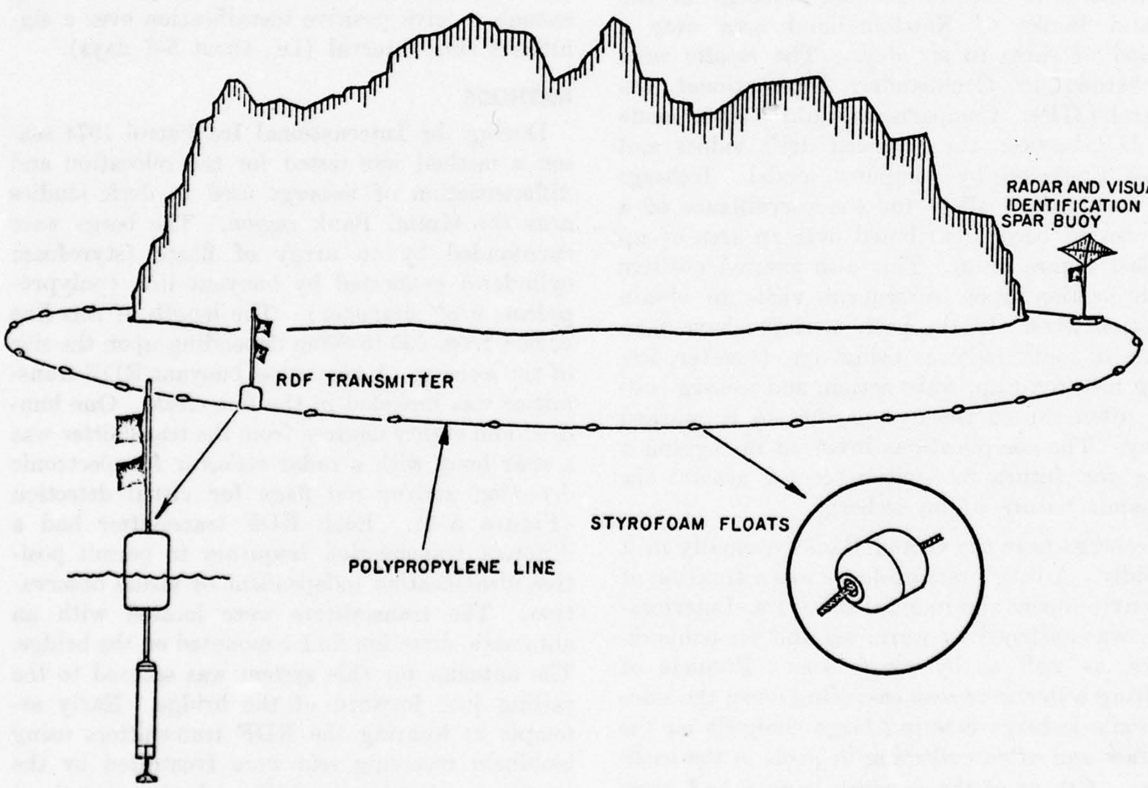

FIGURE A-1—ICEBERG TAGGING ARRAY DEPLOYED DURING IIP 1974

Table A–1.—Iceberg Drift Data from IIP-2-74 Cruise

Iceberg#	Type Size (meters)	# of OBS.	Date/Time (Local) Observed (June 1974) From	To	Vector Averaged Drift Speed (KTS.) $\bar{x}$	Vector Averaged Drift Direction (°T) $\bar{x}$	Vector Averaged Wind Speed (KTS.) $\bar{x}$	Vector Averaged Wind Direction Minus 180° (°T) $\bar{x}$	*Average Angle of the Drift to the Right of the Wind (°) $\bar{x}$ ± s.d.	Ratio of the Average Drift Speed of the Average Wind Speed $\bar{x}$ ± s.d.
1	Medium Pinnacle 21x122	7	20/0911	23/1007	0.2	020	13.9	035	-021 ± 065	.016 ± .006
2	Large Pinnacle 37x137	7	20/0935	26/0348	0.4	156	11.2	041	092 ± 081	.041 ± .033
3	**Medium Drydock 46x101	8	24/1542	28/2300	0.9	198	12.1	134	060 ± 048	.071 ± .031
4	Small Domed 6x30	4	24/1607	26/0844	0.6	182	12.2	108	086 ± 018	.055 ± .012
5	Small Tabular 18x61	4	24/1823	26/0800	0.3	181	12.4	105	086 ± 018	.079 ± .015
6	Very Large Double Pinnacle 53x265	6	26/1700	29/0138	1.1	212	13.5	139	078 ± 020	.085 ± .025
ALL		36							058 ± 064	.056 ± .034

*Negative values indicate a drift angle to the left of the wind
**Iceberg #3 calved into two pieces between 28/0100 and 28/0928 (local)

ICEBERG DRIFT RESULTS

The drift of the six icebergs was determined for the time between observations as often as possible during the period 20/0911 Local to 29/0138 Local June 1974. The icebergs were tracked from 1.6 to 4.8 days. Wind velocities were logged hourly by the CGC EVERGREEN's bridge watch. All icebergs tracked during the experiment were found in the area bounded by 44–30N to 47–30N and 47–00W to 48–30W. Air temperatures during the iceberg tagging project ranged from 3.9°C to 9.4°C with an average about 6.4°C. The surface sea water temperature for the same period ranged from 1.1°C to 10.6°C with an average about 3.9°C. The weather was predominantly overcast with fog and visibility typically less than 100 yards for the entire drift survey. The sea state was moderate to calm. The data from observations taken during the second Ice Patrol cruise of 1974 are summarized in Table A–1.

The vector averaged drift for the bergs varied from 0.2 kts for iceberg #1 to 1.1 kts for iceberg #6. The average drift speed to average wind speed ratio ranged from 0.16 to 0.85. An expendable surface current probe was deployed in the van of iceberg #6 which measured a surface current of 1.23 kts setting at 193°T. This compared to the iceberg drift of 1.1 kts at 212°T. The wind was 13.5 kts from 319°T.

The drift angle with respect to the wind direction had a large standard deviation which was ±18° to ±81°. Furthermore, a number of observations (14%) indicated drift angles to the left of the wind. Ettle (1974) had iceberg drift data from past Ice Patrol cruises that gave a range of standard deviations for drift angles of ±54° to ±104°.

DISCUSSION OF ICEBERG DRIFT

Iceberg drift studies have always been handicapped by a lack of precise navigation and current information. In this study, satellite navigation was used for the first time, but since tagging the iceberg was of primary interest few current measurements were taken. Budinger (1960) put together a drift experiment that used current measurements, but was plagued by the poor precision of the geomagnetic electro-kinetograph (GEK) surface current measurements and by inadequate navigation. Ettle (1974), in his analysis, did not treat the currents in the area of the drifting iceberg. Therefore, his results do not separate out the effect of the wind. In order

to obtain precise positions, some investigators placed marker buoys in shallow water and plotted positions relative to the buoy. This procedure had at least two drawbacks. The first was that the berg could only be tracked for a limited distance before the marker had to be moved. Second, using a buoy required that the drift study be conducted in shallow water where tidal currents and turbulence had a much greater impact than in the deeper ocean.

Now that satellite navigation is available, it is possible to plan a more precise and more sophisticated approach to iceberg drift.

The elements that contribute to the dirft of an iceberg are as follows:

a. The current system, composed of barotrophic and baroclinic components, is probably the most influential factor in iceberg drift.

b. The wind has two effects on iceberg drift. First, the drag on the iceberg itself by the wind. Second, the wind-included current which adds to and modifies whatever surface current already exists.

c. The Coriolis effect which arises from the rotation of the earth and acts to the right of the velocity of the iceberg in the Northern Hemisphere.

d. Finally there is a small force associated with the slope of the sea surface which tends to move the iceberg downhill.

An iceberg moving with a uniform velocity has no net force acting on it; all forces balance. When one of the forces change, the iceberg accelerates or decelerates until a new equilibrium of forces is obtained. The net force can be determined by the change of the drift vector over some time interval.

At the same time that the drift of the iceberg is measured, measurement of wind, calculation of the geostrophic current, and the surface current intergrated over the depth of the iceberg must be made. The force exerted by a fluid on an immersed body is a function of both the drag of the fluid on the body and of the square of the velocity of the object relative to the fluid. Since the iceberg is affected by both air and water, there are two drag terms. If these drag coefficients are determined from the experimental data, then for a given wind velocity, the velocity of the wind driven surface current and the velocity of the iceberg can be calculated by integrating the drag forces over a time period necessary to reach equilibrium.

REFERENCES

Budinger, T. F., 1960: Wind Effect on Icebergs. (U.S. Coast Guard, unpublished manuscript).

Ettle, Robert E., 1974: Statistical Analysis of Observed Iceberg Drift. *Arctic* 27 (2): 121–127.

Kollmeyer, R. C., R. M. O'Hagan and R. M. Morse, 1965: Oceanography of the Grand Banks Region and the Labrador Sea in 1964. U.S. Coast Guard, Oceanographic Report No. 10.

APPENDIX B

1974 LABRADOR COAST OCEANOGRAPHIC SURVEY

Smith (1937), using oceanographic station observations collected by the CGC MARION in 1928 and CGC GENERAL GREENE in 1933, has written the most definitive work concerning the characteristics of the Labrador Current over the Labrador continental shelf. In July of 1948, 1949, and 1962, the International Ice Patrol conducted limited oceanographic cruises into the Labrador Sea region without further studying Labrador Current properties. In the summer of 1965, an oceanographic survey was conducted from Cape Dyer, Baffin Island to South Wolf Island, Labrador neglecting the area from about Cape White Hankerchief, Labrador to South Wolf Island (Kollmeyer, 1967). During July and August of 1966, an extensive oceanographic study was done of the circulation of Hudson Strait and its contiguous areas. Again little oceanographic work was done along the coast of Labrador. In July 1968, a 48 station oceanographic survey consisting of four sections was conducted between Hamilton Inlet, Labrador and Belle Isle Strait (Andersen, 1971). Unfortunately three or four more sections were not placed between Hamilton Inlet and Cape White Handkerchief to tie together all of the oceanographic work done by the Ice Patrol in that area.

From 8–14 September 1974, an oceanographic survey was done over the Labrador continental shelf from Bears Gut fjord to South Wolf Island, Labrador (fig. 1). Since the CGC EDISTO (WAGB 284) was coming from Iceland, the Labrador Sea section was also occupied. This survey should definitively determine the relative velocity field in a previously neglected region. Results of this field work will appear in the Unit's Oceanographic Report Series (CG 373).

REFERENCES

Andersen, H. (1971) The Labrador Current Between Hamilton Inlet and the Strait of Belle Isle. U.S. Coast Guard Oceanographic Report No. 41, CG 373–41.

Kollmeyer, R. C. (1967) Contribution to and effect of the Hudson Strait outflow on the Labrador Current. Oceanography of the Labrador Sea in the vicinity of Hudson Strait in 1965. U.S. Coast Guard Oceanographic Report No. 12, CG 373–12.

Smith, E. H., F. M. Soule, and O. Mosby (1937) The Marion and General Greene Expeditions to Davis Strait and Labrador Sea. Scientific results, part 2, physical oceanography, U.S. Treasury Department Coast Guard Bulletin No. 19, 259 pp.

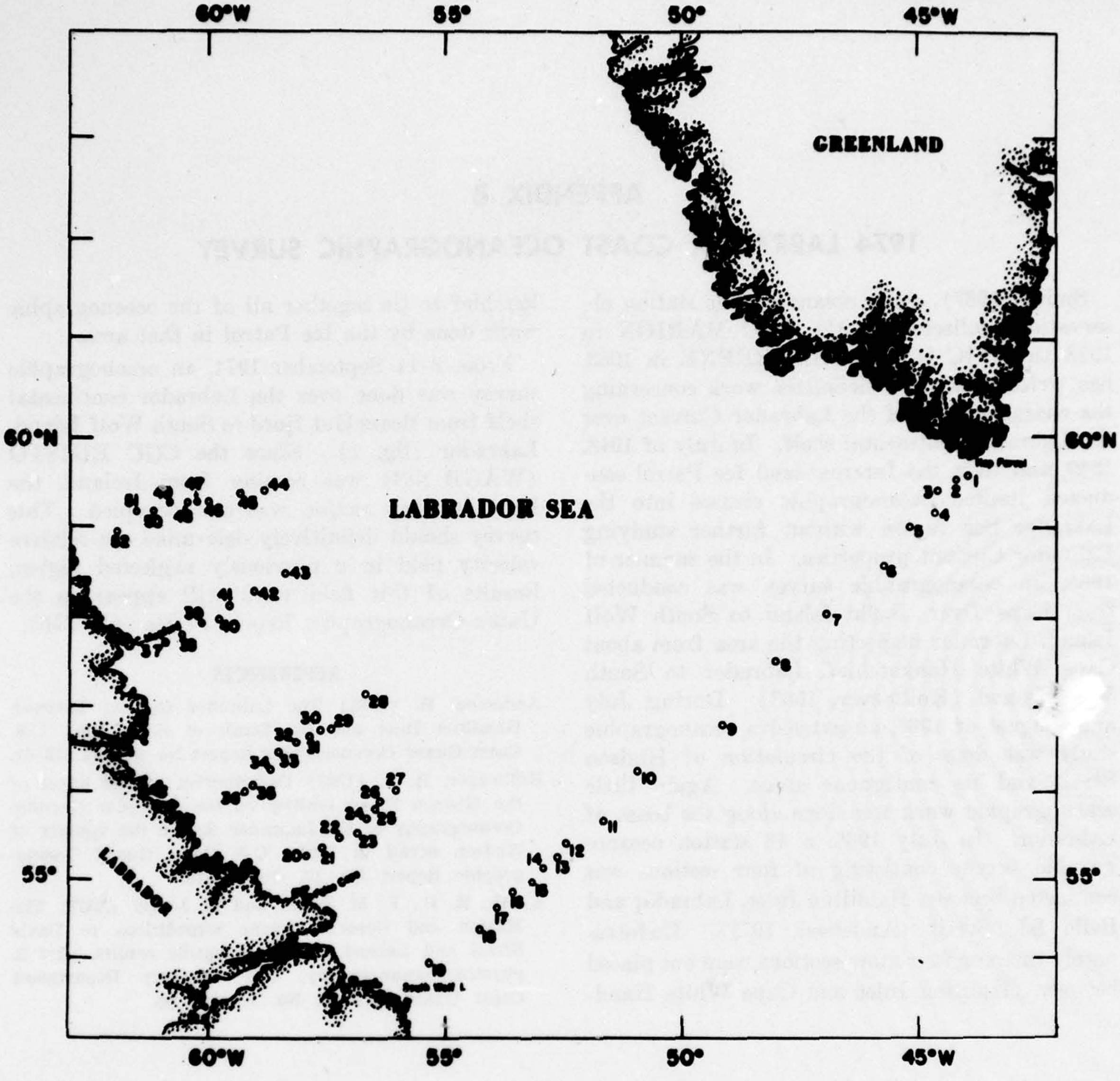

Figure 1.—Oceanographic stations occupied by CGC EDISTO 8–14 September 1974.

APPENDIX C

AN EVALUATION OF THE AIRBORNE RADIATION THERMOMETER FOR THE INTERNATIONAL ICE PATROL

by LTJG S. R. OSMER, USCG

Late in the 1974 Season, an airborne radiation thermometer (ART) was made available to Commander, International Ice Patrol, and was deployed for utilization and evaluation by the Ice Patrol Detachment. In 1954 the Ice Patrol conducted unsuccessful tests with an airborne radiation thermometer for the purpose of distinguishing between iceberg and non-iceberg radar targets under conditions of poor visibility. This device was called a bolometer. During the 1964 season, an airborne radiation thermometer was tested by the International Ice Patrol. While the actual water temperatures recorded by this instrument were not considered sufficiently reliable, the instrument was useful in detecting changes in surface water temperature, and therefore in locating the approximate position of the Labrador Current and its branches.

The main reason Commander, International Ice Patrol requested the ART was to, hopefully, improve the operational efficiency of the flights by determining sea surface temperature (SST) in the vicinity of icebergs to provide optimum deterioration data. Commander, International Ice Patrol , on a regular basis, "melts" icebergs. This "melt" is based upon conservative historical temperature deterioration data. The resulting survey could also map temperatures in the adjacent areas for continued iceberg melting as they drift.

Additionally, it was thought possible that the Labrador Current could be monitored on a continuous basis during routine flights. Although the Labrador Current is salinity driven, many of its features can be identified from themal measurements as can the northern wall and eddies of the North Atlantic Current. These determinations should then aid in predicting the direction of iceberg drift due to surface currents.

After a training period in June, the ART was flown on thirteen (13) ice reconnaissance flights in July. The normal altitude for such flights was 1000 feet. The data collected were then plotted and contoured. These isotherms were compared with the mean sea surface temperatures for July and the weekly SST charts produced by the Canadian Maritime Command (MARCOM). The MARCOM SST charts are used by the Ice Patrol Headquarters for the regular computing of iceberg life expectancy. These SST data are displayed in figures C–1 through C–7. All temperatures are in degrees Celsius (°C).

Four Ice Patrol flights were made during 7 to 10 July, four flights during 16 to 20 July, and five flights during 24 to 30 July. The flight tracks are shown on the ART charts. The gaps in data are due to the continuing problem International Ice Patrol faces each year on the Grand Banks—bad weather, in particular heavy fog, rain, and low-lying clouds. The ART is weather-limited in that the concentration of water vapor in the sampling column will cause a biased reading due to back radiation. Thus, if the surface to be observed is obscured by weather the ART cannot be used with any great weather reliability.

The ART SST for 7 to 10 July shows a very good agreement with the MARCOM Halifax 5 to 8 July SST. The 8° to 16° isotherms compare very well, while the 6° isotherm on the MARCOM chart tends to be further north and east than as shown on the ART chart.

For the next period, 16 to 20 July, the flights were characterized by large gaps in data collection due to weather. This can be inferred from the chart. The ART SST shows a fair comparison with the MARCOM SST for the 6° to 12° isotherms. The 4° isotherm on the MARCOM

chart seems to indicate a warmer condition than that which the ART found.

For the next period. 24 to 30 July, the ART SST and MARCOM SST for 25 to 28 July show a very good agreement for the 10° to 16° isotherms. The MARCOM chart reflects a warmer condition by the location of the 8° isotherm as compared with that of the ART.

Though the ART data gathered in 1974 were only during one month, they do illustrate a good comparison with the temperature information presently being used by the Ice Patrol for iceberg deterioration data. The ART has one immediate advantage in that it enables the user to possess near real-time data, whereas the MARCOM charts normally arrive two weeks after the time period for which they were drawn.

Another advantage of the ART, though perhaps not as obvious as that above, is the quality of the data. The MARCOM SST charts are primarily drawn from sea surface temperatures reported by vessels transiting the area. Often, these data are not of the accuracy desired due to vessel measurement procedures and infrequent transits, and large regions may lack any reported temperature. However, the isotherms are faired in to fit the available information as best as possible. With the ART there is a continuous recording of temperature along the entire flight track, excluding areas of weather, enabling more representative temperature charts to be developed for the areas covered.

Commander, International Ice Patrol intends to utilize the ART during the 1975 Ice Season for the collection of deterioration data, and hopefully for current monitoring.

I would like to thank MST1 Neil O. TIBAYAN for his invaluable assistance in preparing the SST charts.

RELATED REFERENCES

Light, M. *U.S. Coast Guard Airborne Radiation Thermometer (ART) Surveys of Atlantic Coastal Waters*, U.S. Coast Guard Oceanographic Unit. Prepared for the 1968 Meeting of the Committee for the Scientific Exploration of the Atlantic Self (SEAS) November 20–21, 1969.

Daignault, Frank *NEW MISSION*, Oceans Magazine SEP–OCT 1972.

Mean Sea Surface Temperature for July, Fleet Weather Center Norfolk, Virginia.

Sea Surface Temperature Charts (5–8 July 1974, 18–21 July 1974, 28–30 July 1974), Maritime Command Headquarters, Halifax, Nova Scotia, Canada.

Communications, U.S. Coast Guard Oceanographic Unit, Joseph W. Deaver, Senior ART Technician.

International Ice Observation and Ice Patrol Service in the North Atlantic Ocean—Season of 1954, Bulletin No. 40, USCG.

Report of the International Ice Patrol Service in the North Atlantic Ocean—Season of 1963, Bulletin No. 49, USCG.

Report of the International Ice Patrol Service in the North Atlantic Ocean—Season of 1964, Bulletin No. 50, USCG.

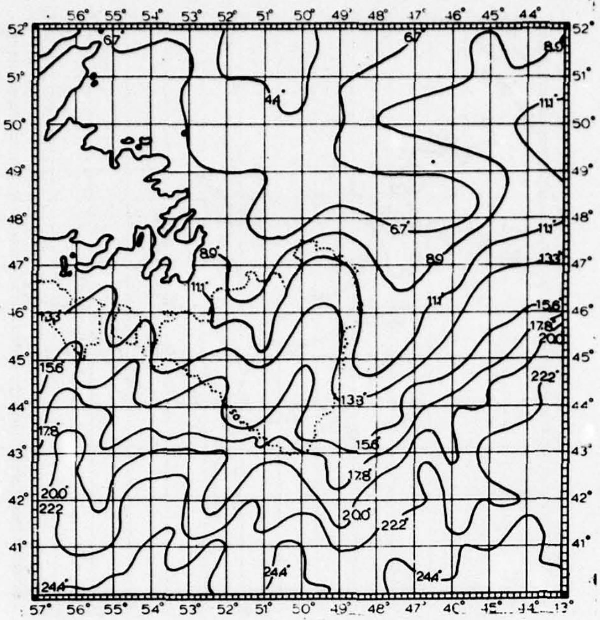

FIGURE C-1.—Mean Sea Surface Temperature for July.

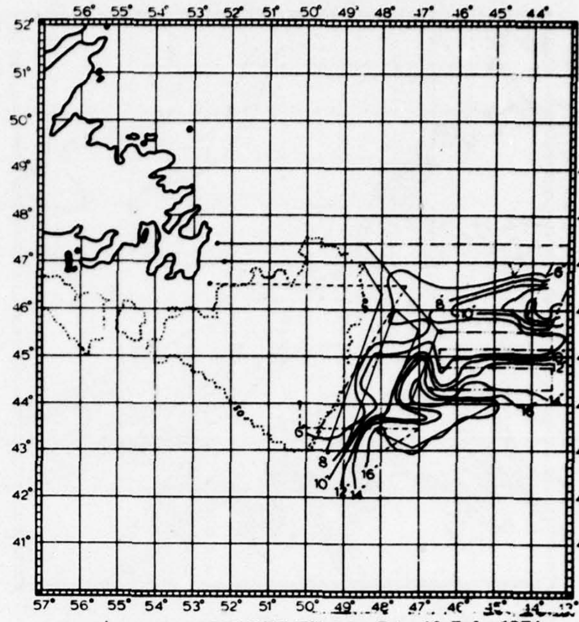

FIGURE C-2.—ART SST Flights, 7 to 10 July 1974.

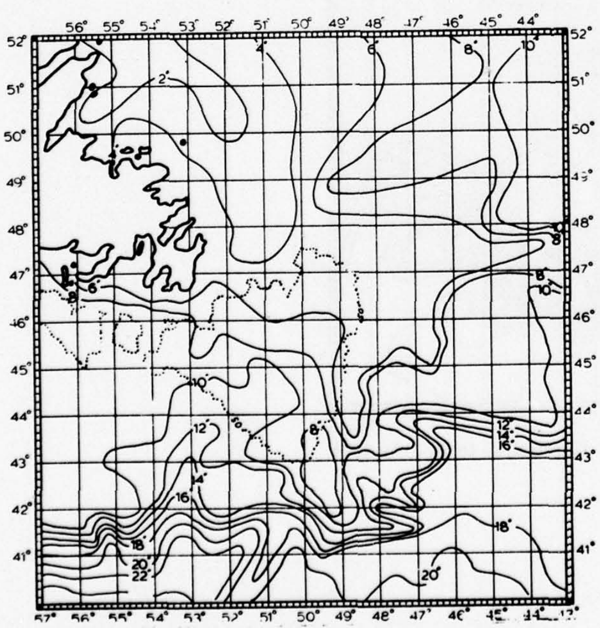

FIGURE C-3.—SST Marcom, Halifax, 5 to 8 July 1974.

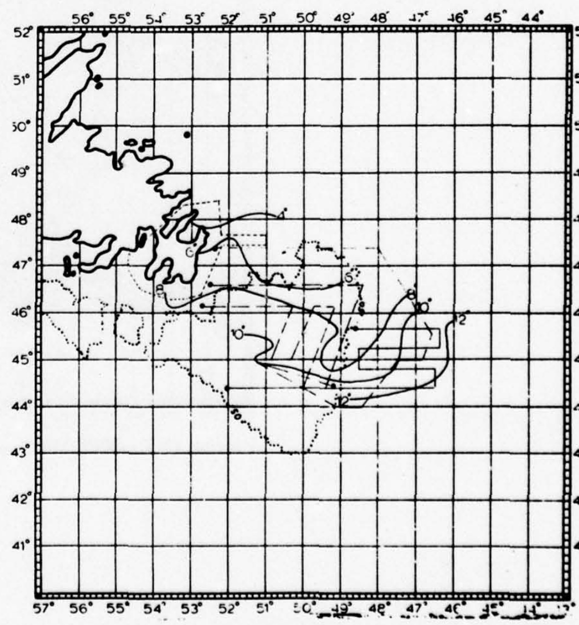

FIGURE C-4.—ART SST Flights, 16 to 20 July 1974.

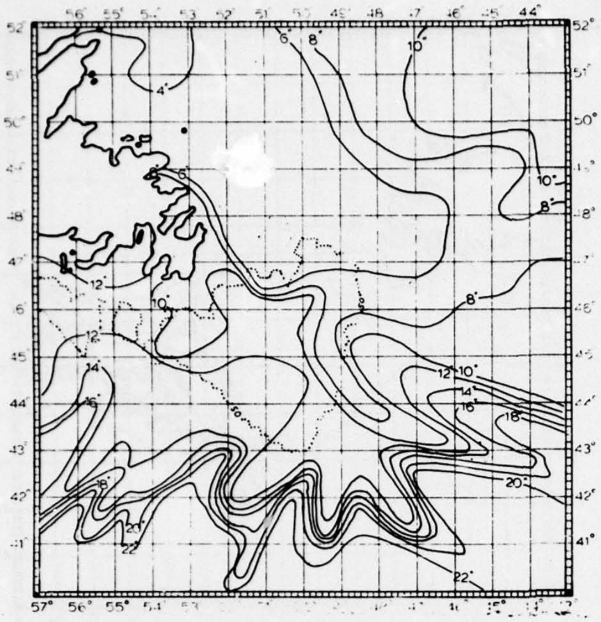

FIGURE C-5.—SST Marcom, Halifax, 18 to 21 July 1974.

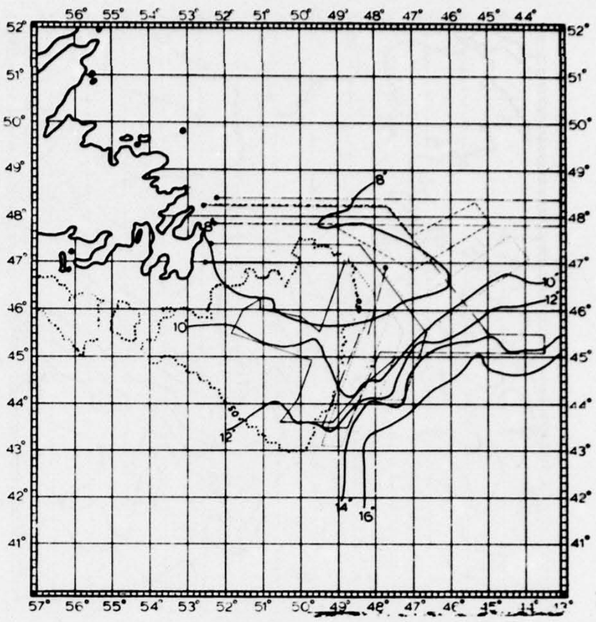

FIGURE C-6.—ART SST Flights, 24 to 30 July 1974.

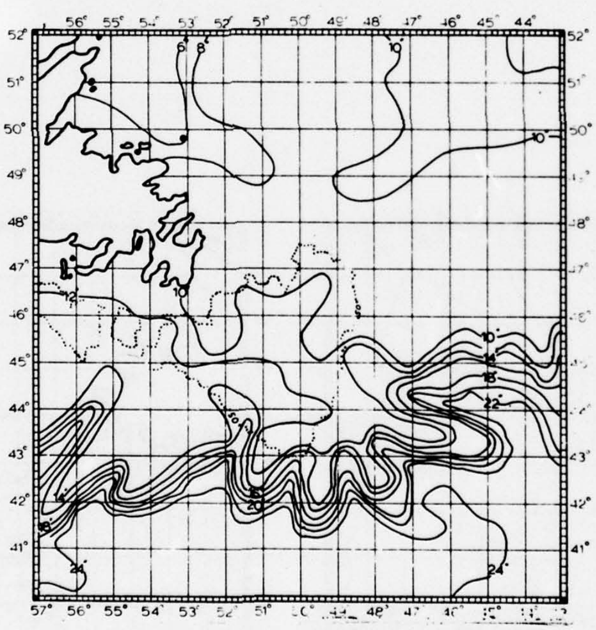

FIGURE C-7.—SST Marcom, Halifax, 25 to 28 July 1974.

APPENDIX D

ERTS–A EVALUATED

by LTJG S. R. OSMER, USCG

In October 1972, Commander, International Ice Patrol began receiving ERTS-A imagery covering the Grand Banks north to 60°N. This is the conclusion reached from two years of viewing this satellite imagery.

ERTS-A (Earth Resources Technology Satellite) was launched on 23 July 1972. The life expectancy was one year. Imagery was still being beamed to earth when ERTS-B was launched on 19 January 1975.

The ERTS mission was to gather high resolution multispectral data of the earth's surface on a global basis. The sensor payload contained two systems to accomplish this mission—a four channel Multispectral Scanner System (MSS) and a three camera Return Beam Vidicon (RBV) system.

The following descriptions are from the ERTS Data Users Handbook. ERTS-A operated in a circular sun synchronous, near-polar orbit at an altitude of 494 nautical miles. It circled the earth every 103 minutes, completing 14 orbits per day and viewed the entire earth every 18 days. The orbit was selected and kept trimmed so that the satellite ground trace repeated its earth coverage at the same local time every 18 day period within 20 nautical miles.

The RBV operated in the range of 0.48 to 0.83 micrometers visible wavelengths. Each camera sensed a diferent spectral band. However, due to its large power demand, this system was rarely used.

The MSS imagery was viewed by the Ice Patrol. The four bands of the MSS were:

Band 4 --------	0.5–0.6 micrometers
Band 5 --------	0.6–0.7 micrometers
Band 6 --------	0.7–0.8 micrometers
Band 7 --------	0.8–1.1 micrometers

All bands were in the visible spectrum for daylight operation. Bands 6 and 7 were near-infrared bands. Photographic products were received in two sizes—70mm and 9.5 inch positive transparencies. The respective scales were 1:3,369,000 and 1:1,000,000.

The MSS gathered data by imaging the surface of the earth in several spectral bands simultaneously through the same optical system. It scaned crosstrack swaths of 185 kilometers (100-nm) square width.

The MSS precision output product had a residual error for positional mapping accuracy of 242 meters.

The July 1972 issue of *Aviation Week and Space Technology* stated the operating resolution of the MSS was expected to be about 225 feet. The September 1973 issue of *Environmental Data Service* stated ERTS was capable of resolution approaching 100 meters (about 330 feet).

Thomas Ragland, Assistant Project Manager ERTS/NIMBUS, NASA/GSFC, in correspondence with International Ice Patrol Headquarters in July 1972, stated that MSS Bands 5 and 6 were best for sighting icebergs. Under cloud free conditions, because of the good contrast between the ice and water in these bands, icebergs with exposed areas down to about 0.02 square kilometer (0.01 square miles) could expect to be seen.

Barnes (1973) stated that ice features as small as small floes (20 to 100m) across could be detected. He also stated that the MSS–4 and MSS–5 bands appeared to be best for mapping ice boundaries, whereas the MSS–7 band provided greater detail in the ice features. After a limited examination of color products, he felt there was no significant advantage in the use of color data for ice mapping. The size of features somewhat smaller than 100m across could be measured from enlarged ERTS prints. Most im-

portant, Barnes (1973) stated that although larger icebergs could be seen, it was difficult to distinguish them from ice floes.

Late November 1972, Commander, Interna tional Ice Patrol submitted with Dr. Albert Rango, Hydrologist of the Earth Survey Sciences Office, a research proposal to NASA for analysis of data from ERTS-B. Dr. Rango's investigation (1973) dealt with the satellite capabilities for locating Arctic icebergs for possible use in supplementing fresh water supplies in coast areas. Naturally, Commander, International Ice Patrol was interested in utilizing the satellite to locate, identify, and categorize the icebergs as to size in an attempt to predict the severity of the ice seasons, follow the drift of the bergs, and monitor them while they were present on the Grand Banks. This imagery was only expected to supplement, not replace, current ice reconnaissance methods.

In his proposal Rango (1973) stated that MSS bands 5 and 7 would be most useful in detecting differences that might have been relatively subtle. Band 5 would show the best contrast between ice and water, and Band 7 would distinguish between solid ice and ice with melt water on the surface or mixtures of ice and water. The report envisioned classifying icebergs greater than 100 meters in length (or surface areas greater than .01km^2). The following table appeared in the proposal, and summarizes what the investigators expected to be able to see with ERTS-B.

Table 1.—Description of icebergs according to length and type

Size (except tabular type)	*Length (meters)*
Growler* –	<6
Bergy Bit*	6—15
Small Iceberg**	15—61
Medium Iceberg	61—122
Large Iceberg	122—213
Very Large Iceberg	>213
Size of tabular type	
Small**	<91
Medium	91—213
Large	>213

* will not be observable from ERTS-B

** *will probably not be observable from* ERTS-B

In July 1974, Dr. Rango's proposal was not accepted by NASA.

ERTS-A was not designed for oceanographic use, but primarily for earth surface applications. This has tended to limit the quantity and quality of significant results within the oceanographic discipline. ERTS-A is best suited for land and near coastal utilization.

Ice Patrol received third generation photo graphic products. The generation number assigned to photographic products is referenced to the initial output from the video tapes. This output is first generation, each successive photographic product generated adds one generation. Some resolution is lost with each generation.

For the time frame 15 January 1973 to 31 August 1973 in the area bounded by 40°N, 52°N, 40°W, and 57°W, there are 420 ERTS scenes. Likewise, for 1 March 1974 to 15 August 1974, for the same area, there are 478 scenes. The imagery was viewed, with the attempt of locating icebergs, not sea ice, and comparing with known berg locations. All four bands were viewed in many of the scenes. Band 7 seemed to provide the best contrast between the water and an object.

No icebergs were observed. Some of the ice floes may have been icebergs, but without ground truth to verify, there was no way of stating such with any certainty.

One glaring fact which emerged during the imagery viewing was the number of scenes practically useless due to cloud cover. Thus, the Ice Patrol problem of weather affects another remote sensing venture. The following is a breakdown of the cloud cover on the imagery:

	Total percent of scenes	
Percent of Cloud Cover	*1973*	*1974*
100	25	29
90 or more	39	51
80 or more	48	60
70 or more	55	68
60 or more	60	74
50 or more	65	78

The vast majority of the scenes viewed were those with less than 50% cloud coverage.

ERTS-A imagery has limited International Ice Patrol application due to:

(1) *Resolution*—advertised resolution of about 100m is not fine enough to identify an iceberg that would normally reach the Ice Patrol area. Icebergs possessing surface areas greater than $400m^2$ constitute 65% of the total iceberg population. Icebergs with surface areas of $1000m^2$ comprise less than 25% of the population. The $0.01km^2$ resolution of the ERTS-A provides identification of less than 1% of the icebergs of interest to the Ice Patrol.

(2) *Cloud cover*—the cloud/fog blanket normally present on the Grand Banks during several months of the Ice Season does not allow penetration by ERTS-A sensors. ERTS-B carries the same instrument package as ERTS-A. ERTS-C, tentatively scheduled for launch in CY–78, will have a MSS band 5 which will be in the near-infrared range.

(3) *Frequency of area coverage*—the same area is covered every 18 days, though at a latitude of of 40° image overlap is approximately 34.1%, 50° is 44.8%, and 60° is 57%. (Data Users Handbook) The frequency of coverage does not allow for the continuous monitoring of icebergs and their drift—a requirement for Ice Patrol utilization.

(4) User availability—Wiesnet (et al, 1974) states ERTS-A data is not suitable for immediate forecasting due to the great time lag in the user receiving the information. There is usually a 3 week delay from the time GSFC receives the imagery till the user receives it. Ice Patrol found this to be the case also.

Though ERTS holds no present promise for iceberg detection and tracking, Commander, International Ice Patrol is closely following satellite development and application for possible future utilization.

Other satellite imagery has been reviewed in the past by Ice Patrol, among these are the ESSA series, NIMBUS series, NOAA series, and the SMS/GEOS satellite. All are meteorological satellites with 1km resolution. The Ice Patrol utilizes the meteorological satellites for weather information for flight planning and for the sea ice edge. The GEOS satellite also has the capability for taking radiance temperature measurement. (VAETH, 1972) Though this has not at present been utilized by the Ice Patrol, future planning has this under consideration.

In CY 1978, NASA intends to launch SEASAT-A (Sea Satellite). The objectives of SEASAT are to demonstrate a capability to measure global ocean dynamics and physical characteristics, provide data for user applications, and to provide these data real-time to users. The Coast Guard is closely following this project. SEASAT potentially offers—(1) 36-hour repeat coverage globally; (2) data dissemination in near real-time (less than three hours delay advertised); (3) one of the sensors, the Synthetic Aperature Coherent Imaging Radar, will provide all-weather images with resolution approaching 25 meters; (4) another of its four senor systems, the Compressed Pulse Precision Radar Altimeter, will determine the topography of the sea surface which in turn will be related to current determinations. (SEASAT-A Program Plan and Definition)

Hopefully, SEASAT-A's promised potential will find utilization by the International Ice Patrol.

REFERENCES

BARNES, James C., and BOWLEY, Clinton J., "Use of ERTS DATA for Mapping Arctic Sea Ice," *Symposium On Significant Results Obtained from the Earth Resources Technology Satellite-1*, (March 5–9, 1973), 1377–1384.

BARNES, James C., "Evaluace the Application of ERTS-A Data for Detecting and Mapping Sea Ice," *SR No. 126;* March 21, 1973.

FLETCHER, James C., "ERTS-1, Toward Global Monitoring," *Astronautics & Aeronautics*, September 1973, 32–63.

GORAS, John T., LTJG, USCG, *A Report on the Study of Satellite Ice Reconnaissance for U.S. Coast Guard Applications.* (Undated)

HULT, John L., and OSTRANDER, Neill C., *Applicability of ERTS for Surveying Antarctic Iceberg Resources*, November 1973.

McCLAIN, E. P., and DeRYCKE, Richard J., *Sea Ice Motion Along the Labrador Coast as Observed by Satellite*, NOAA/NESS. (Undated)

RANGO, Albert, Dr., Technical Proposal—*Arctic Iceberg Surveys for International Ice Patrol and Water Resources Application*, NASA/GSFC, January 1973.

SHERMAN, John, "Aerospace Remote Sensing Oceanography," *Environmental Data Service*, September 1973, 3–12.

STRICKLAND, Z., MILLER, B., and STEIN, K. J., "Special Report: ERTS," *Aviation Week and Space Technology*, July 31, 1972, 46–62.

STRONG, Alan E., "New Sensor on NOAA-2 Satellite Monitors the 1972–73 Great Lakes Ice Season," *Remote Sensing and Water Resources Management*, June 1973, 171–178.

VAETH, Gordon, "Geostationary Operational Environmental Satellite,"*Environmental Data Service*, February 1972, 4–9.

WIESNET, D. R., McGINNIS, D. F., and FORSYTH, D. G., "The Satellite Record of Snow and Ice In The Great Lakes Basin 1972–73," *17th Conference On Great Lakes Research*, August 1974.

CROWELL, D. W., LT, USCG, *Iceberg Detection, Identification and Tracking for International Ice Patrol Operations*, May 1973.

DATA Users Handbook—Earth Resources Technology Satellite, NASA/GSFC.

Operational Use of ESSA-1 Satellite Photography during the 1966 Season of the International Ice Patrol, CGOU.

Report of the International Ice Patrol Service in the North Atlantic Ocean—Season of 1966, Bulletin No. 52, CG–188-21, USCG.

Prelimary SEASAT-A Program Plan, NASA.

SEASAT-A Definition, NASA/User Meeting, April 25, 1973.

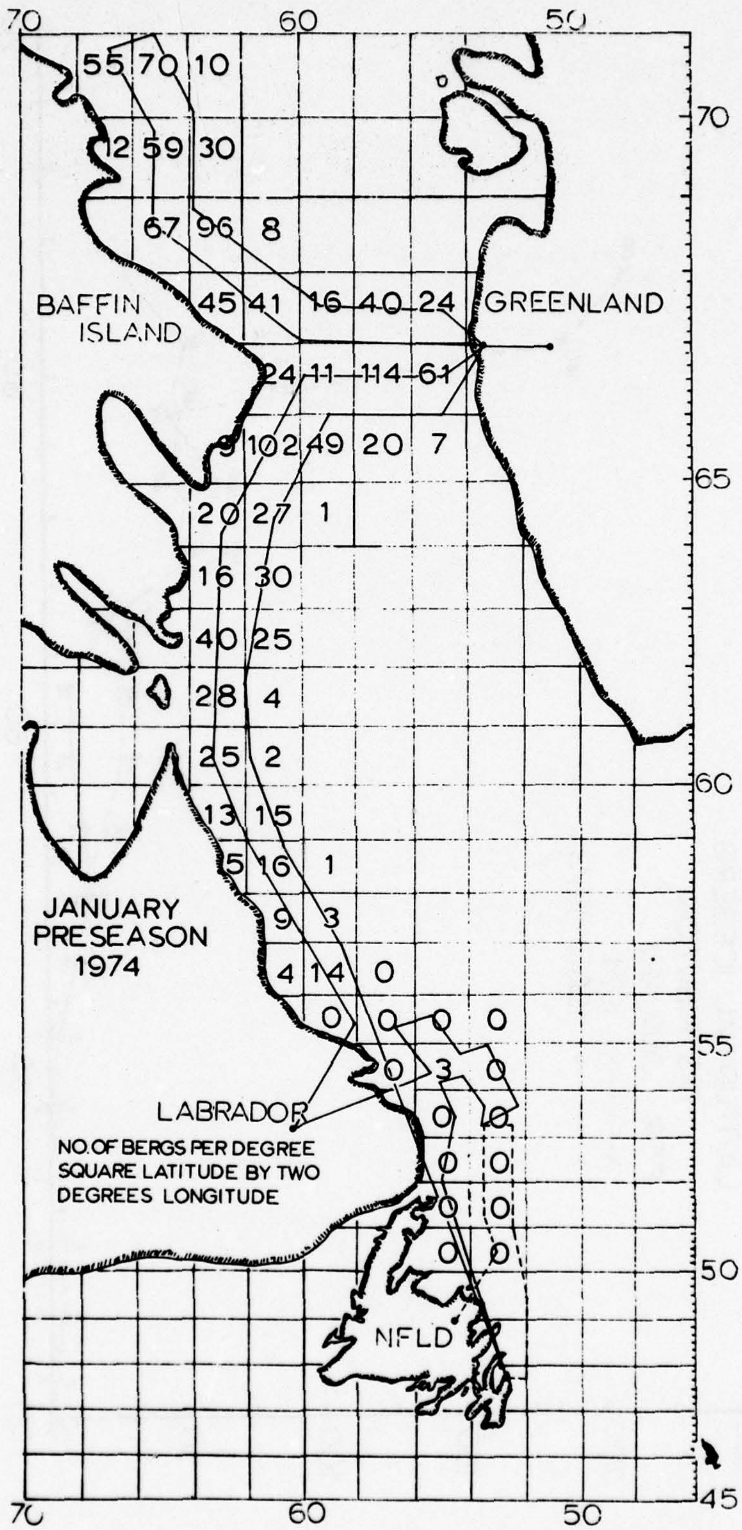

FIGURE 1.—Preseason Iceberg Survey 6–15 January 1974

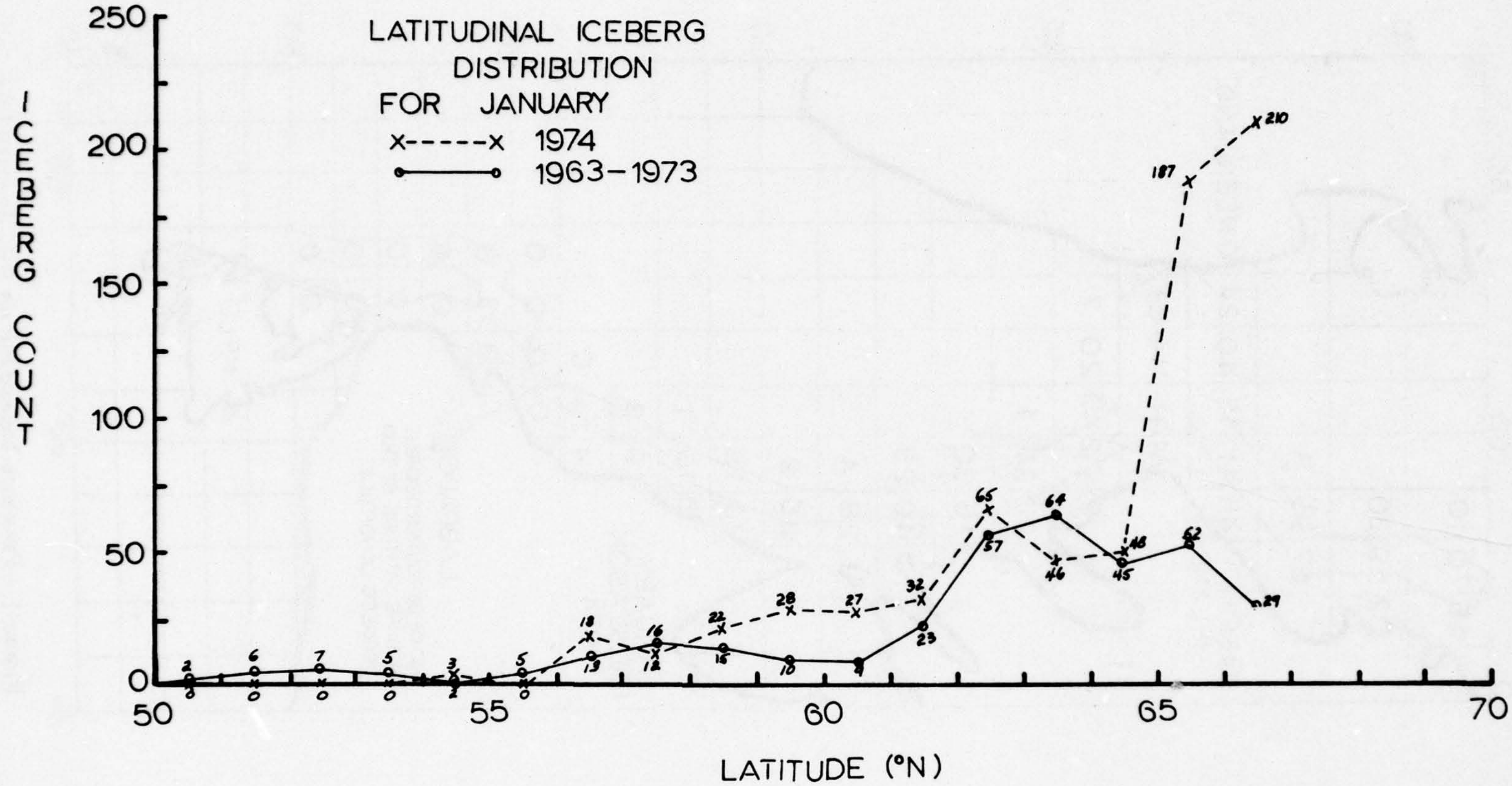

Figure 2.—Latitudinal Iceberg Distribution, January Preseason Flights.

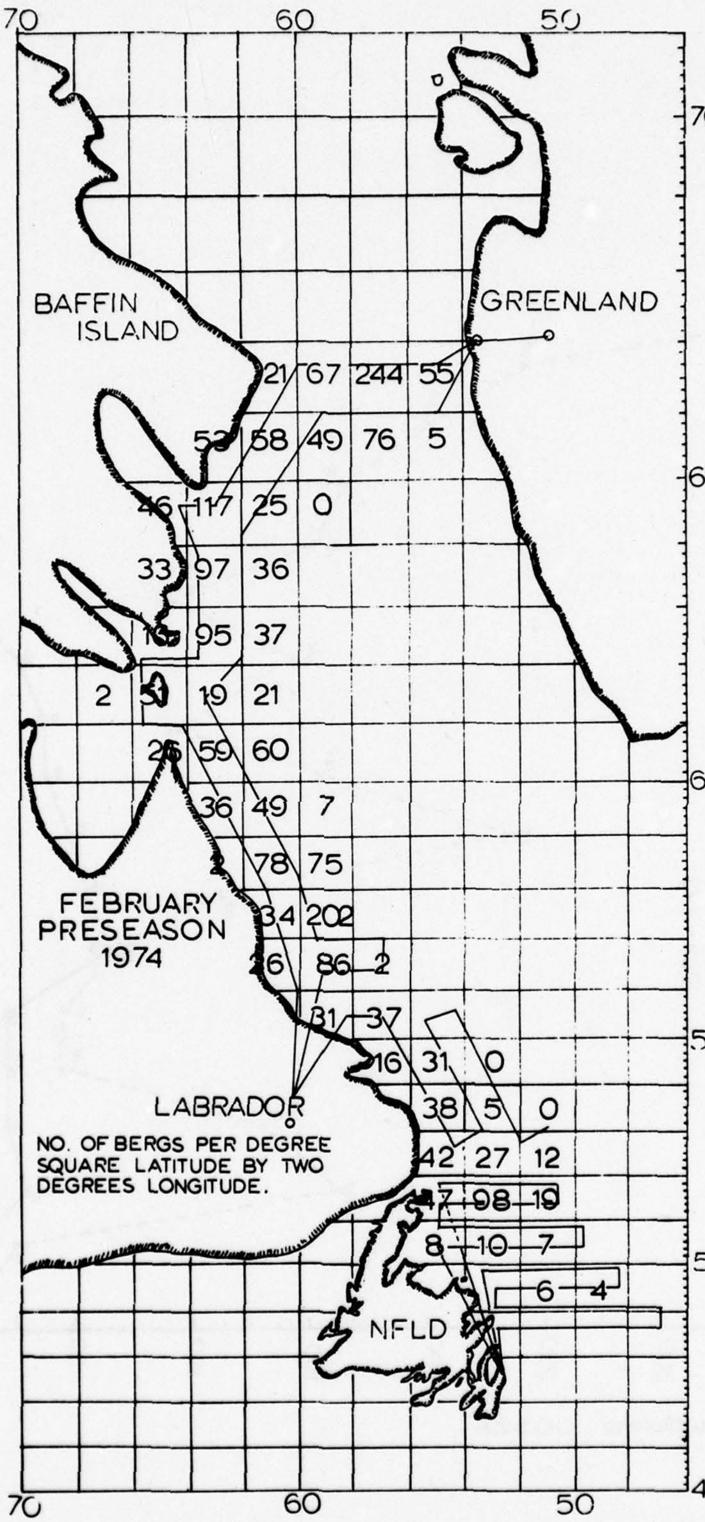

FIGURE 3.—Preseason Iceberg Survey 19 February—1 March 1974.

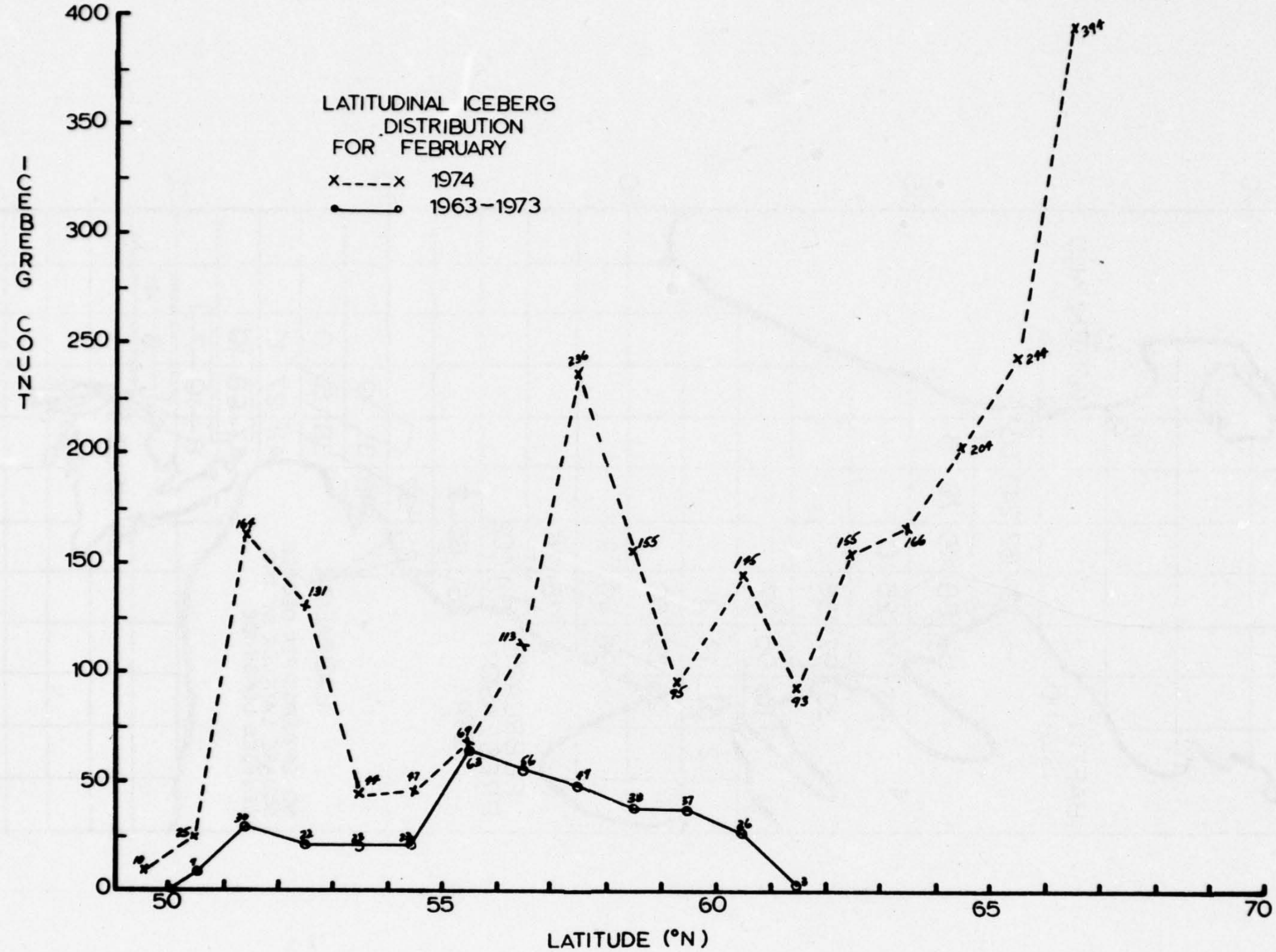

FIGURE 4.—Latitudinal Iceberg Distribution, February Preseaon Flights.

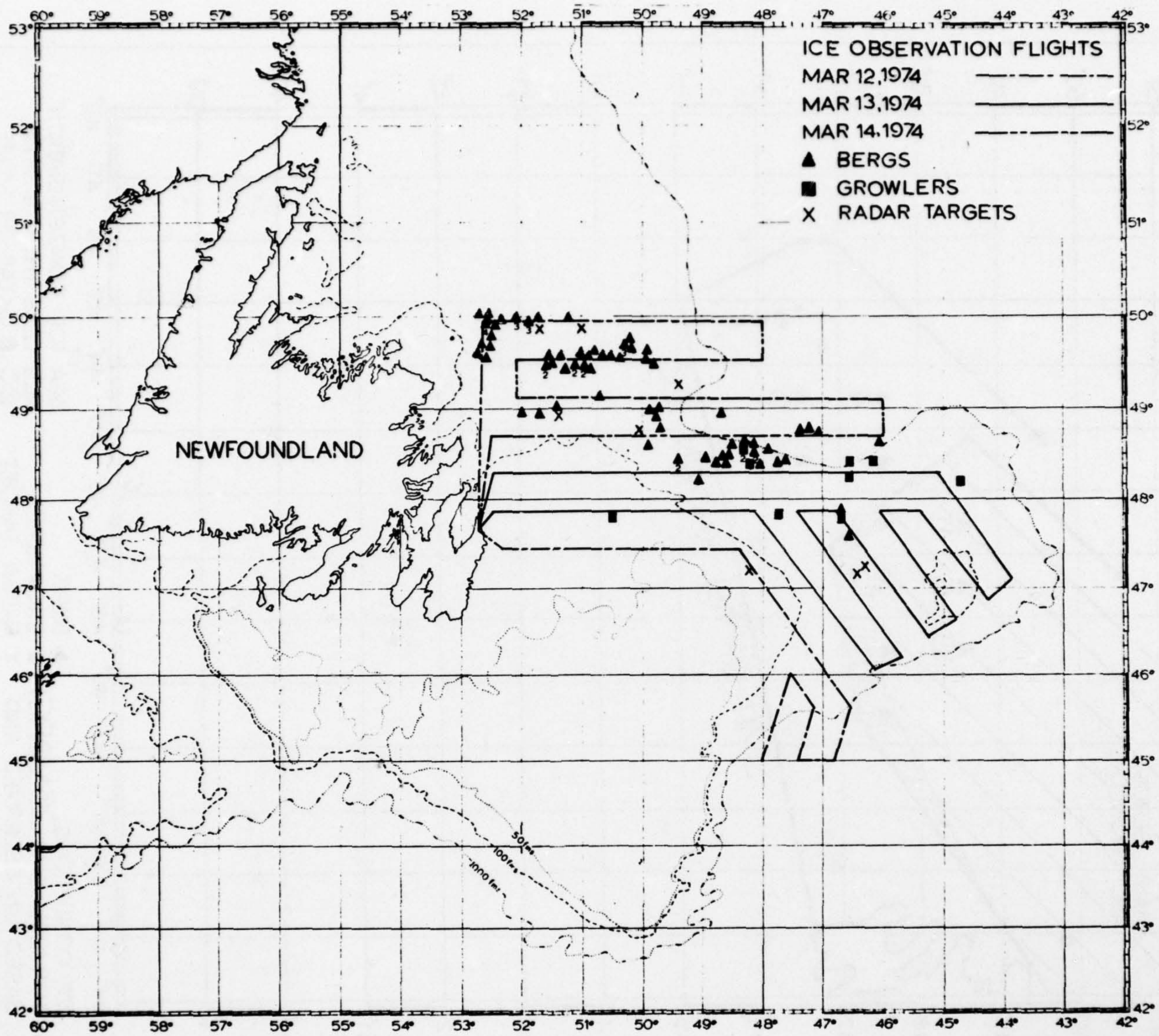

FIGURE 5.—12, 13 & 14 March 74 Preseason Flight Tracks and Iceberg Distribution.

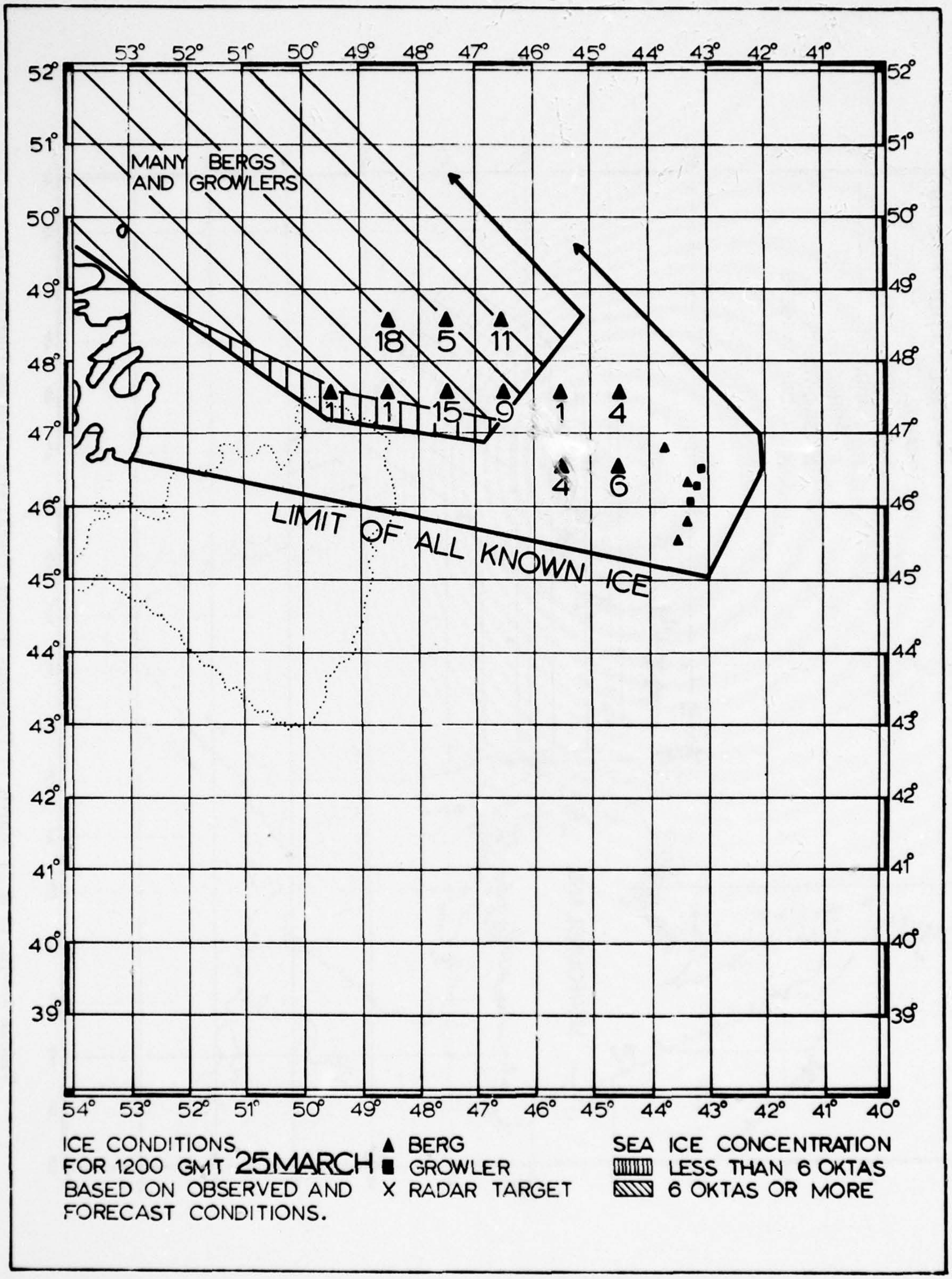

FIGURE 6.—Ice Conditions, 1200 GMT 25 March 1974.

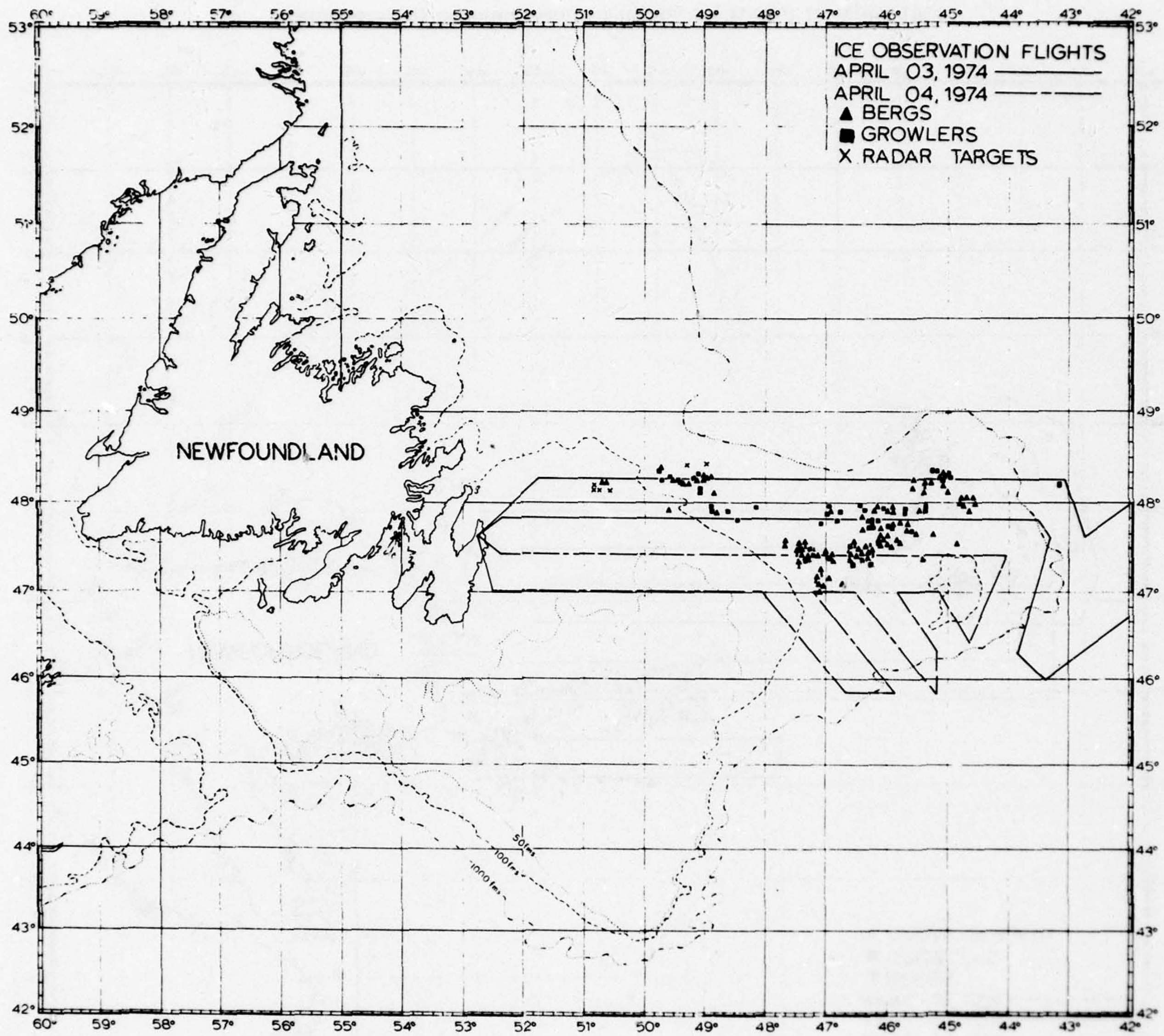

FIGURE 7.—Ice Reconnaissance Flights, 3 and 4 April 1974.

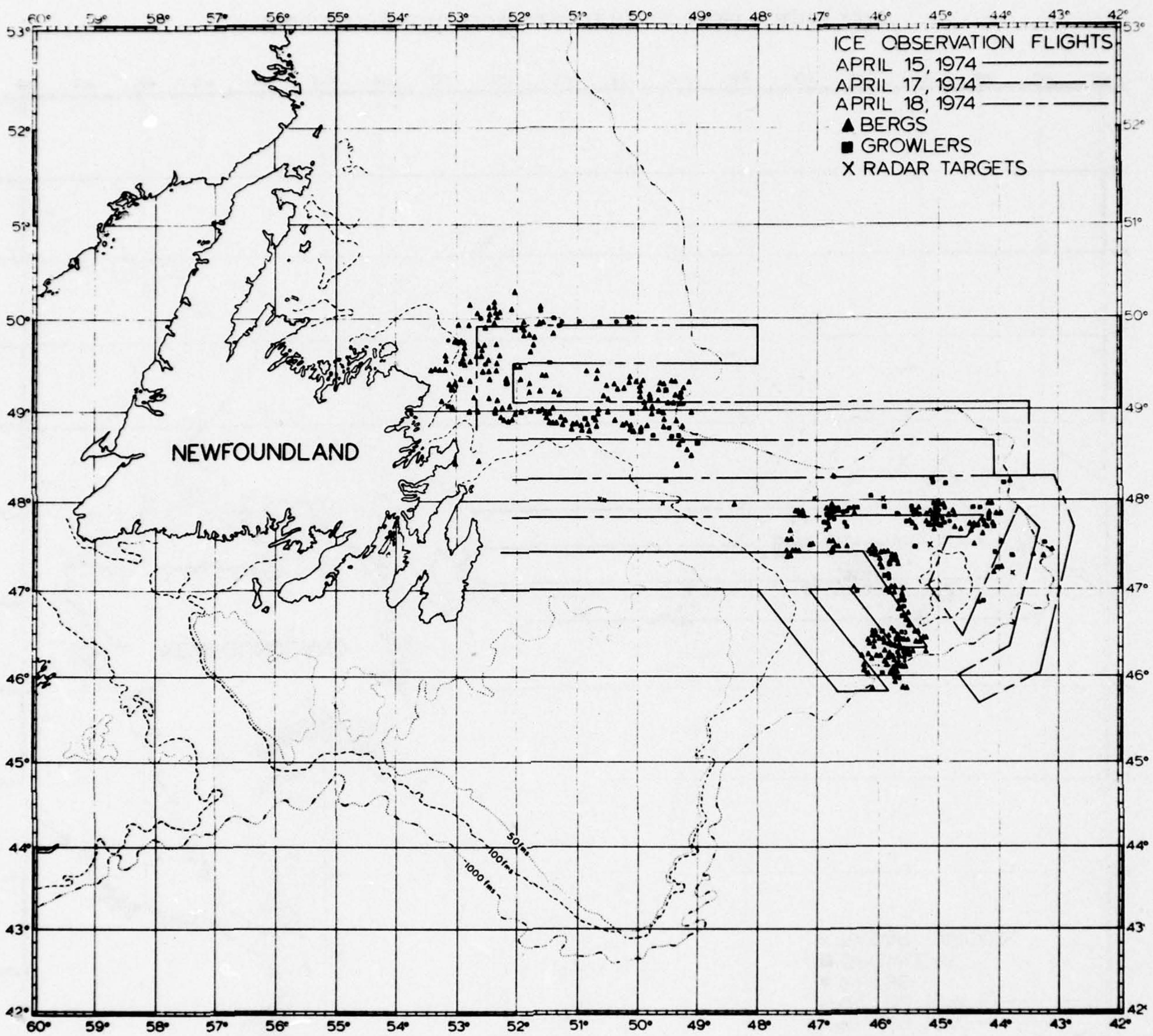

Figure 8.—Ice Reconnaissance Flights, 15, 17 and 18 April 1974.

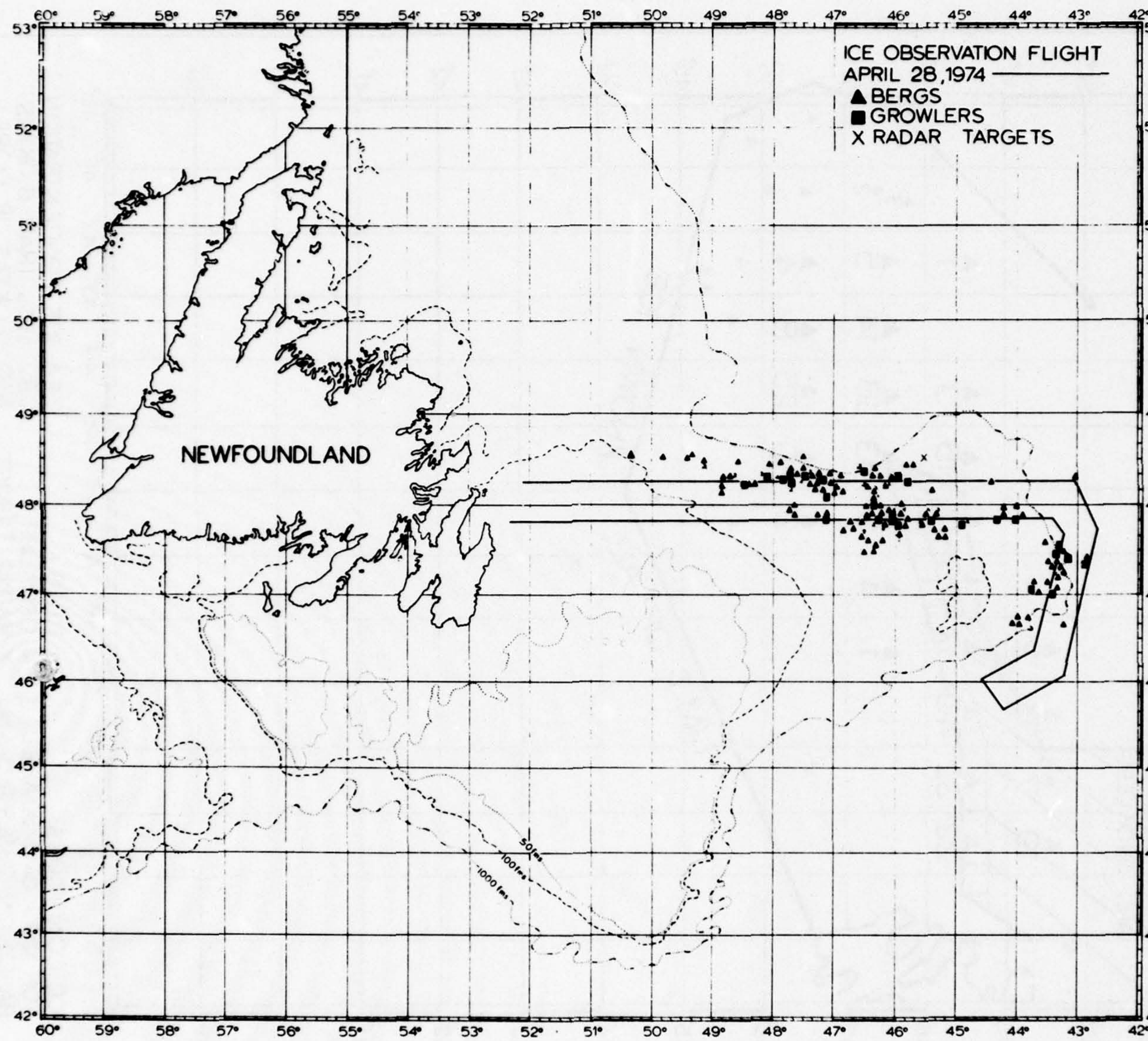

Figure 9.—Ice Reconnaissance Flight, 28 April 1974.

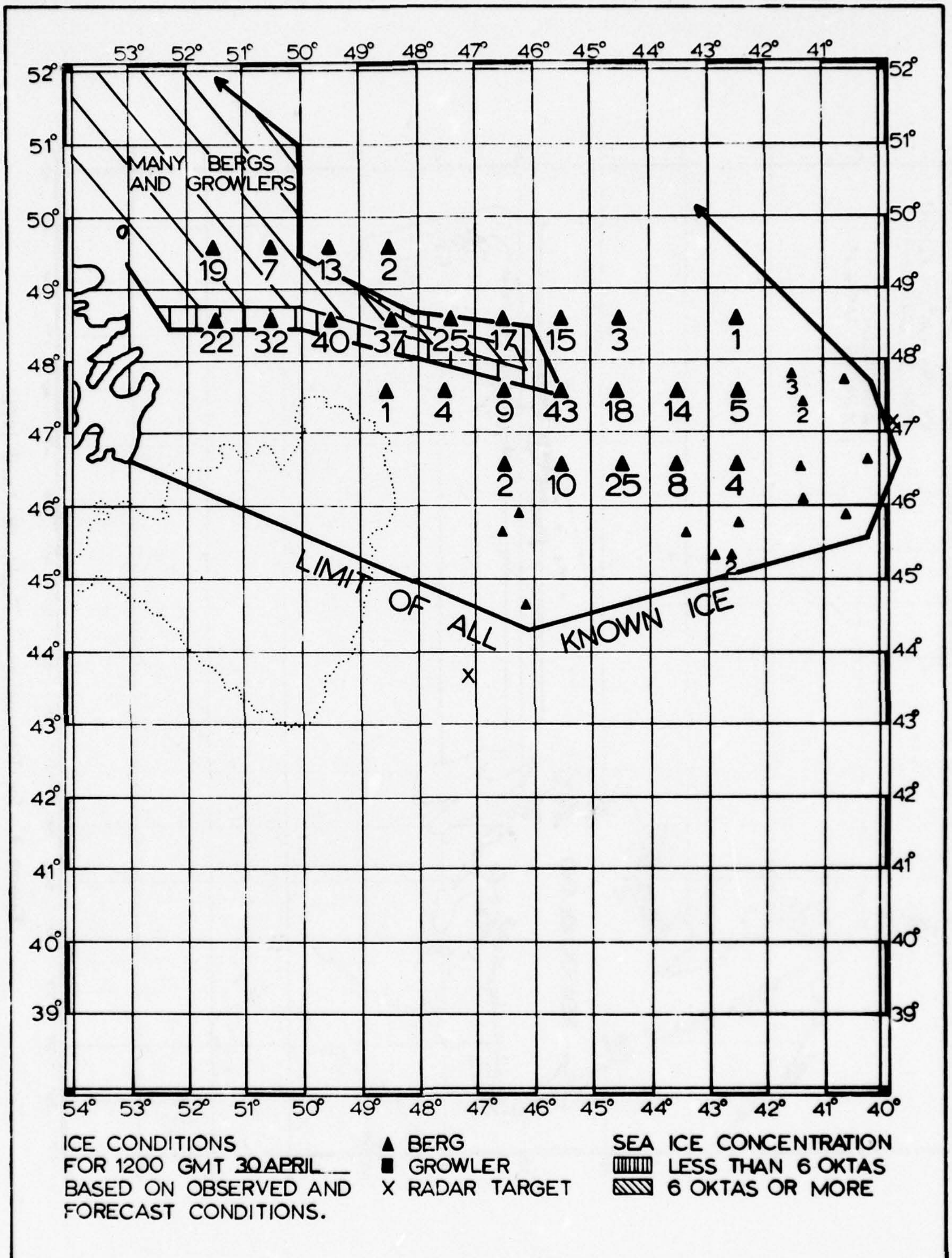

FIGURE 10.—Ice Conditions, 1200 GMT 30 April 1974.

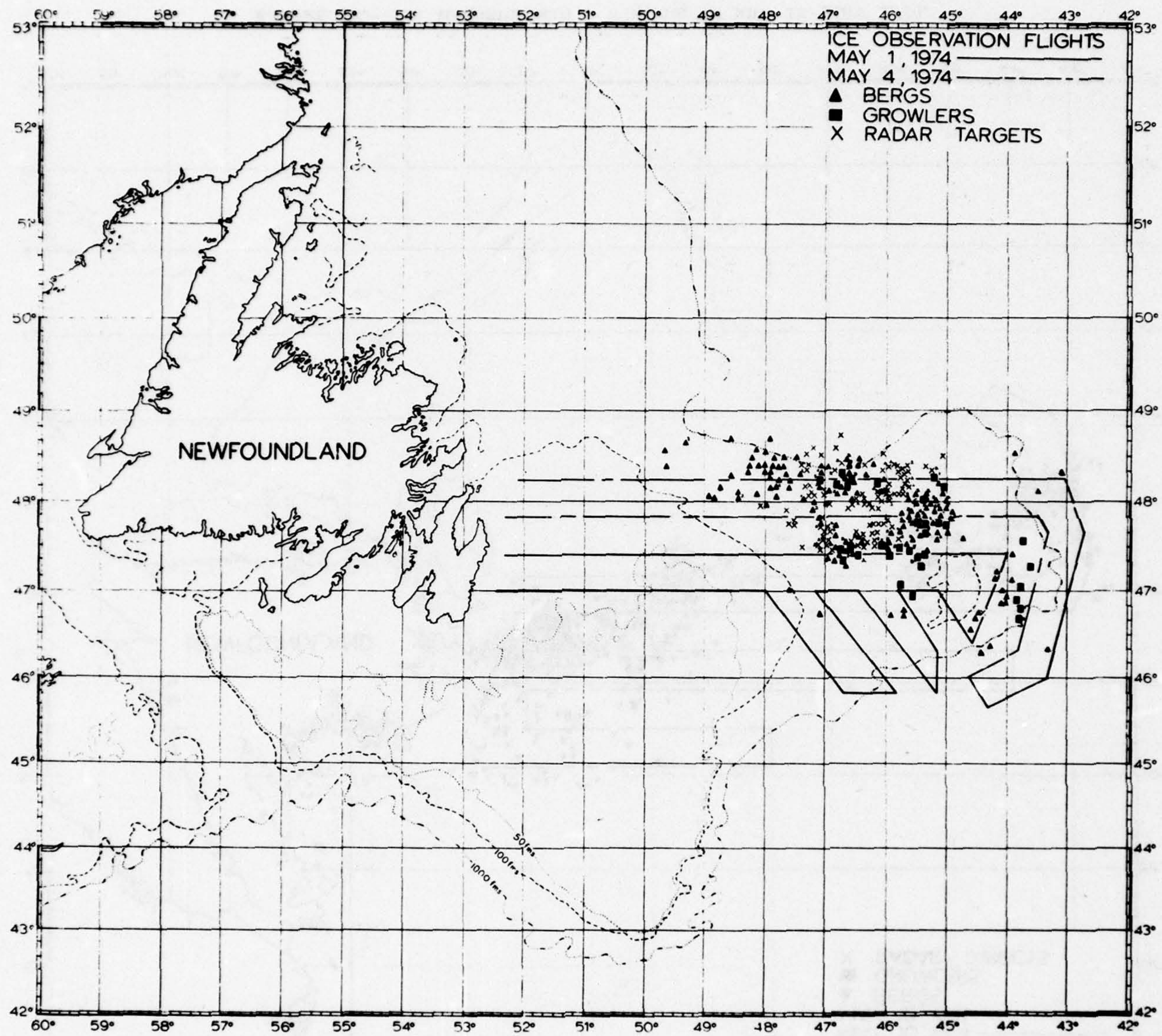

FIGURE 11.—Ice Reconnaissance Flights, 1 and 4 May 1974.

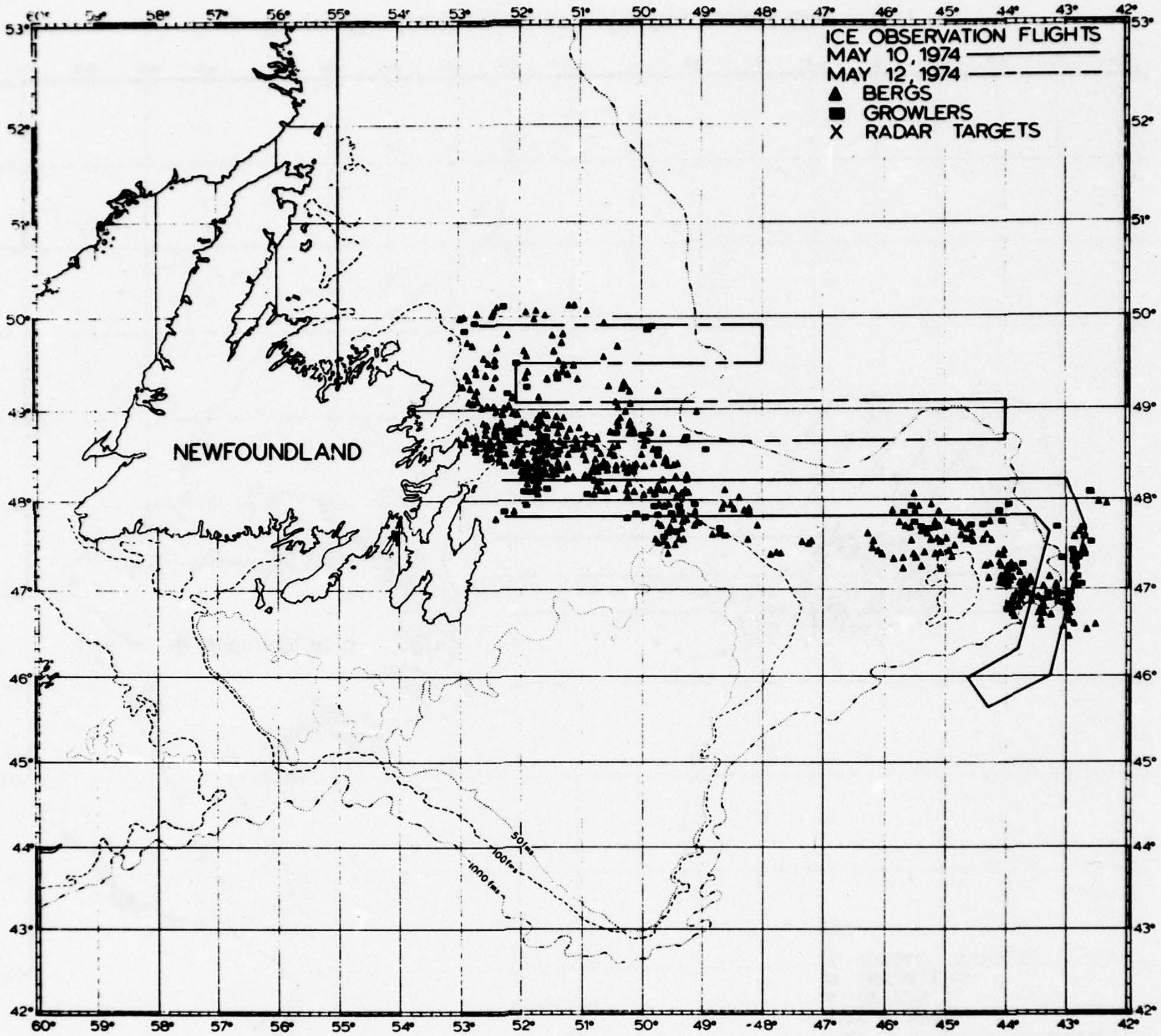

FIGURE 12.—Ice Reconnaissance Flights, 10 and 12 May 1974.

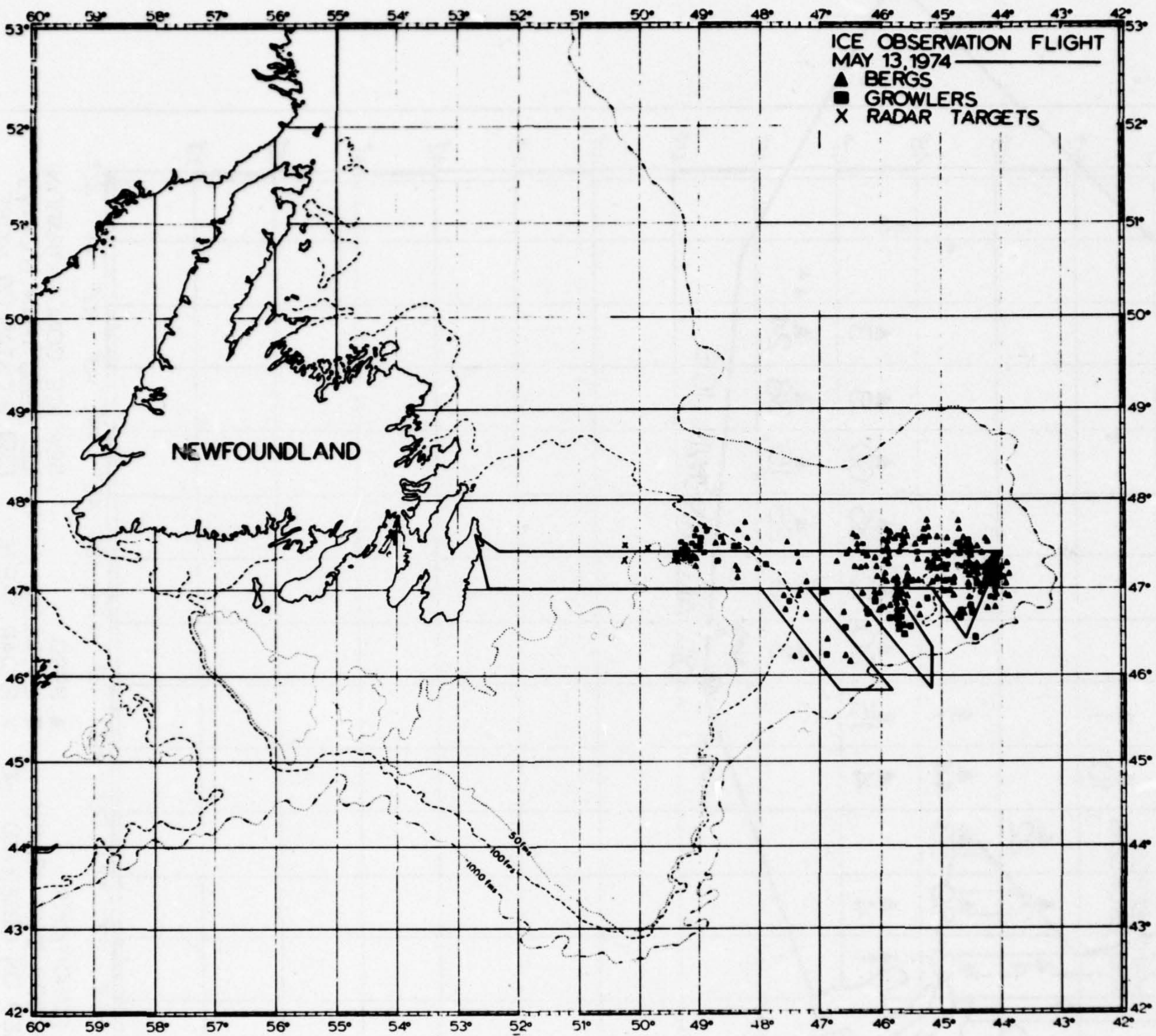

FIGURE 13.—Ice Reconnaissance Flight, 13 May 1974.

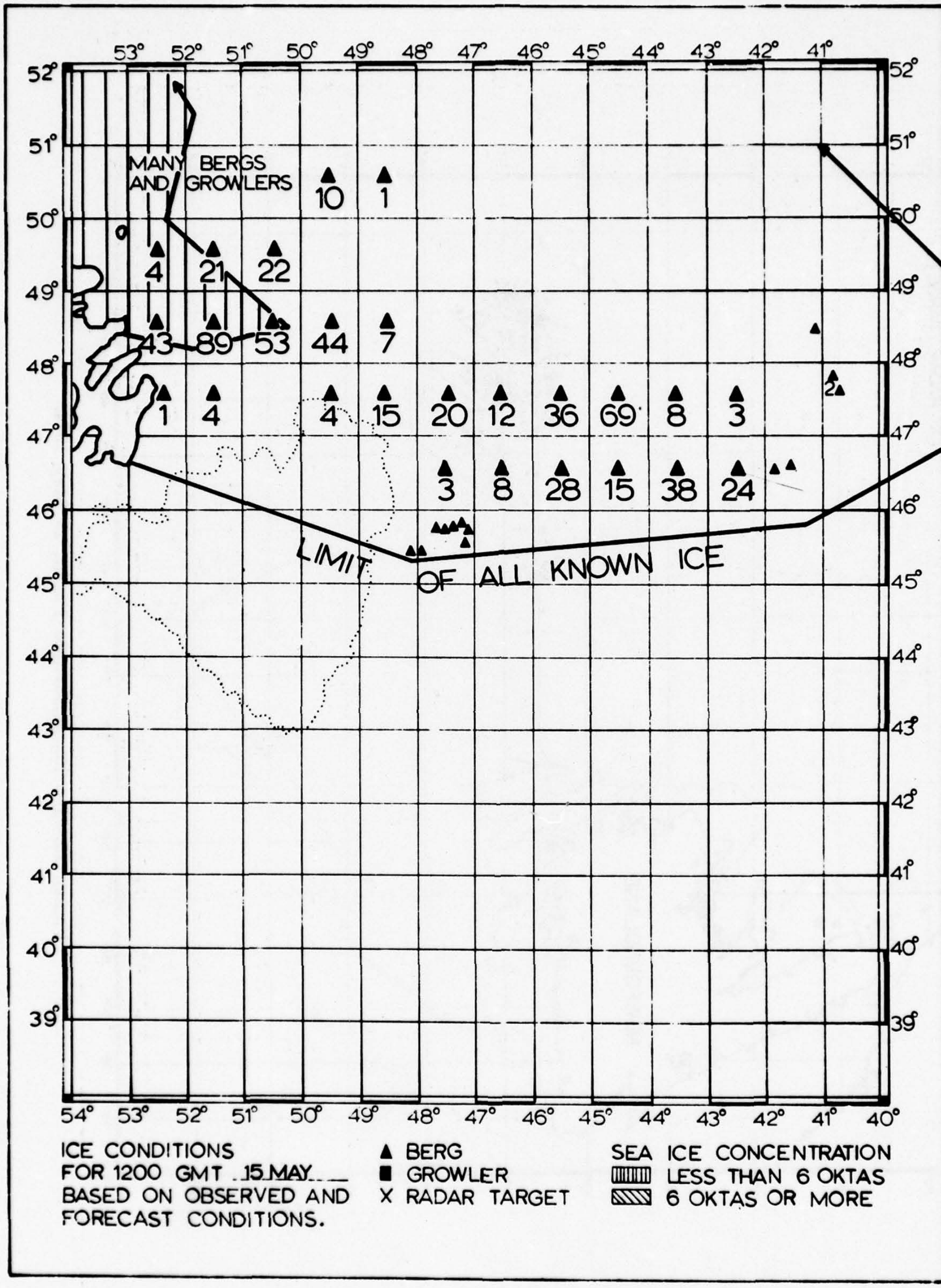

FIGURE 14.—Ice Conditions, 1200 GMT 15 May 1974.

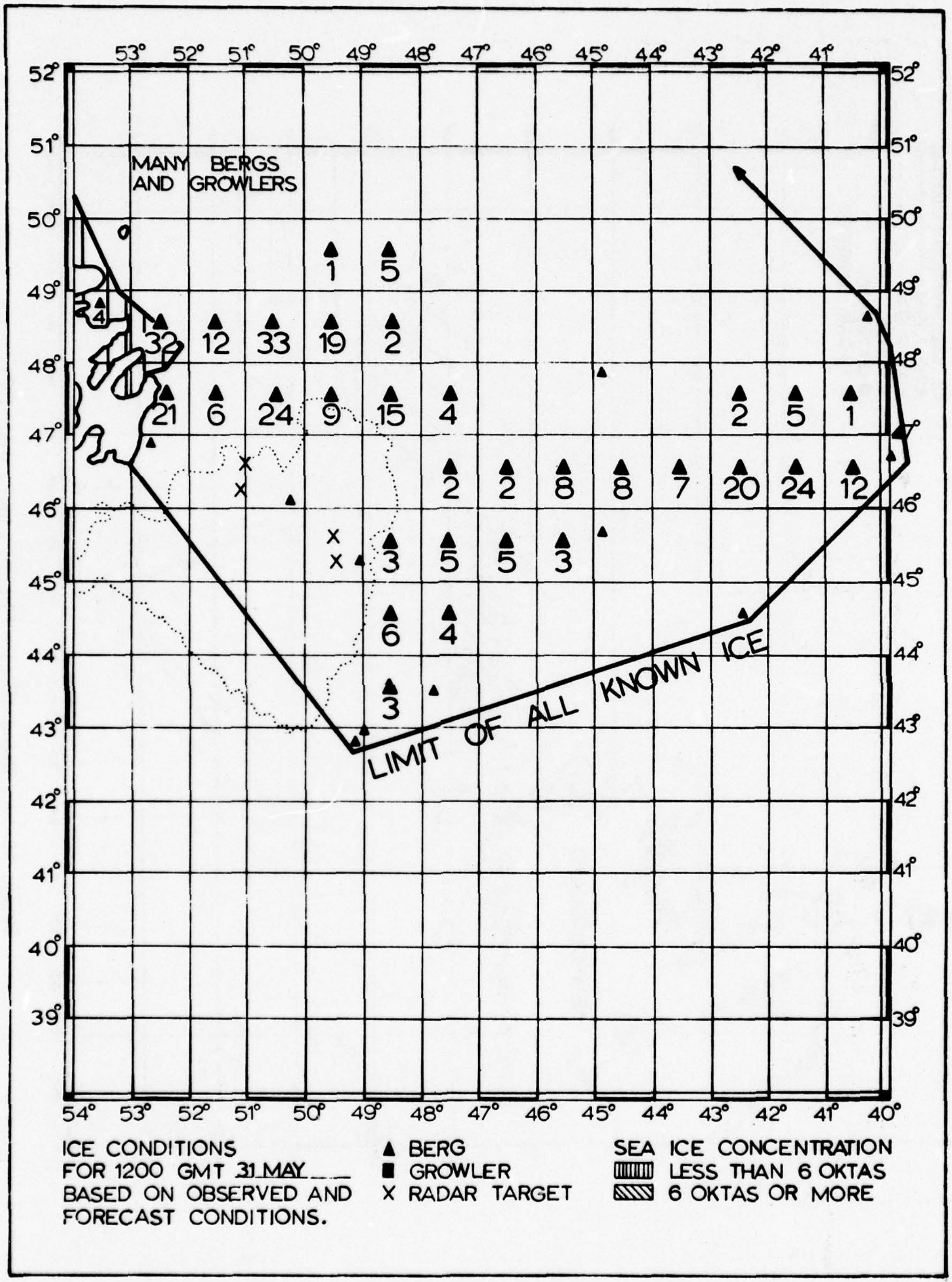

FIGURE 15.—Ice Conditions, 1200 GMT 31 May 1974.

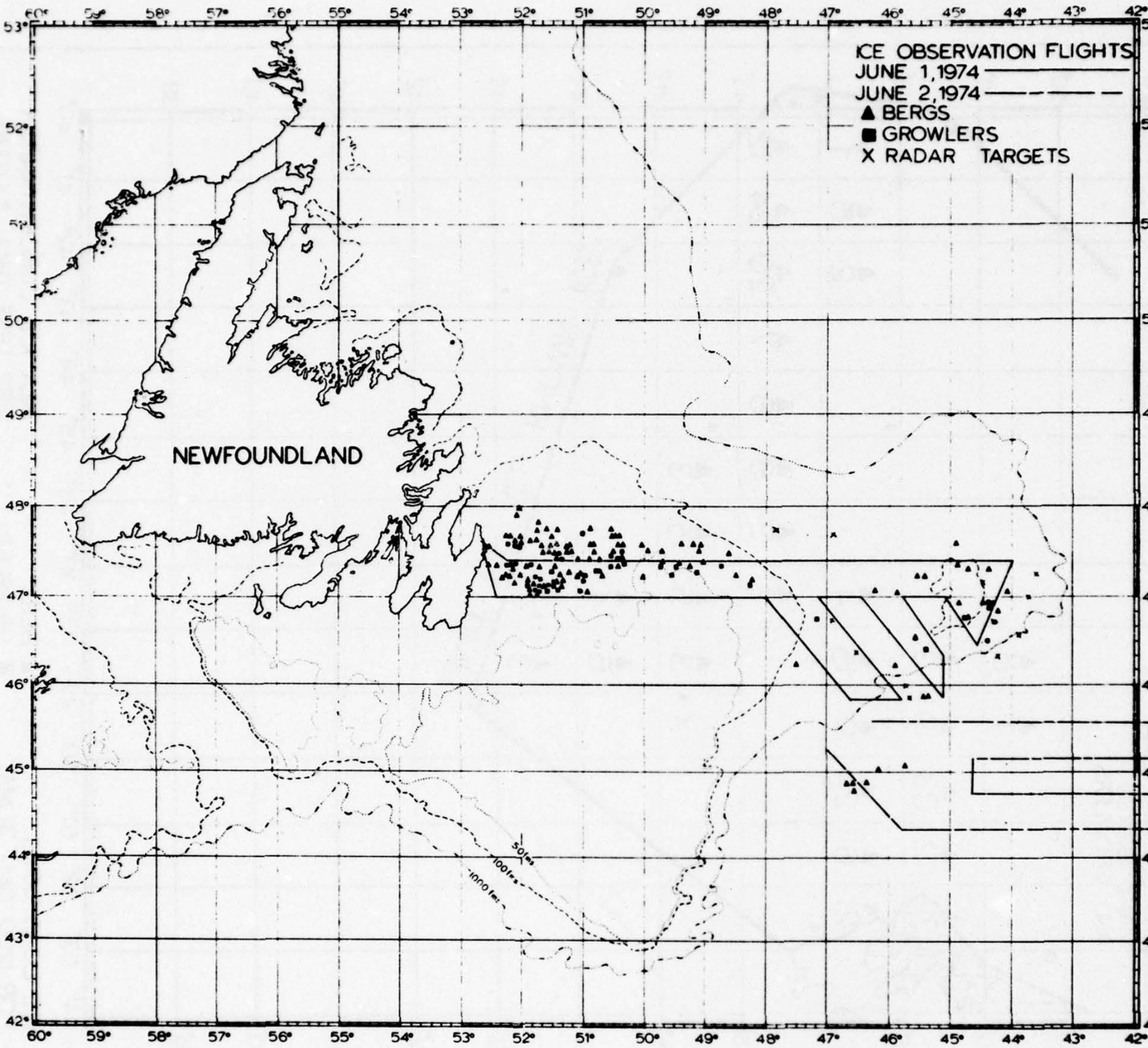

FIGURE 16.—Ice Reconnaissance Flights, 1 and 2 June 1974.

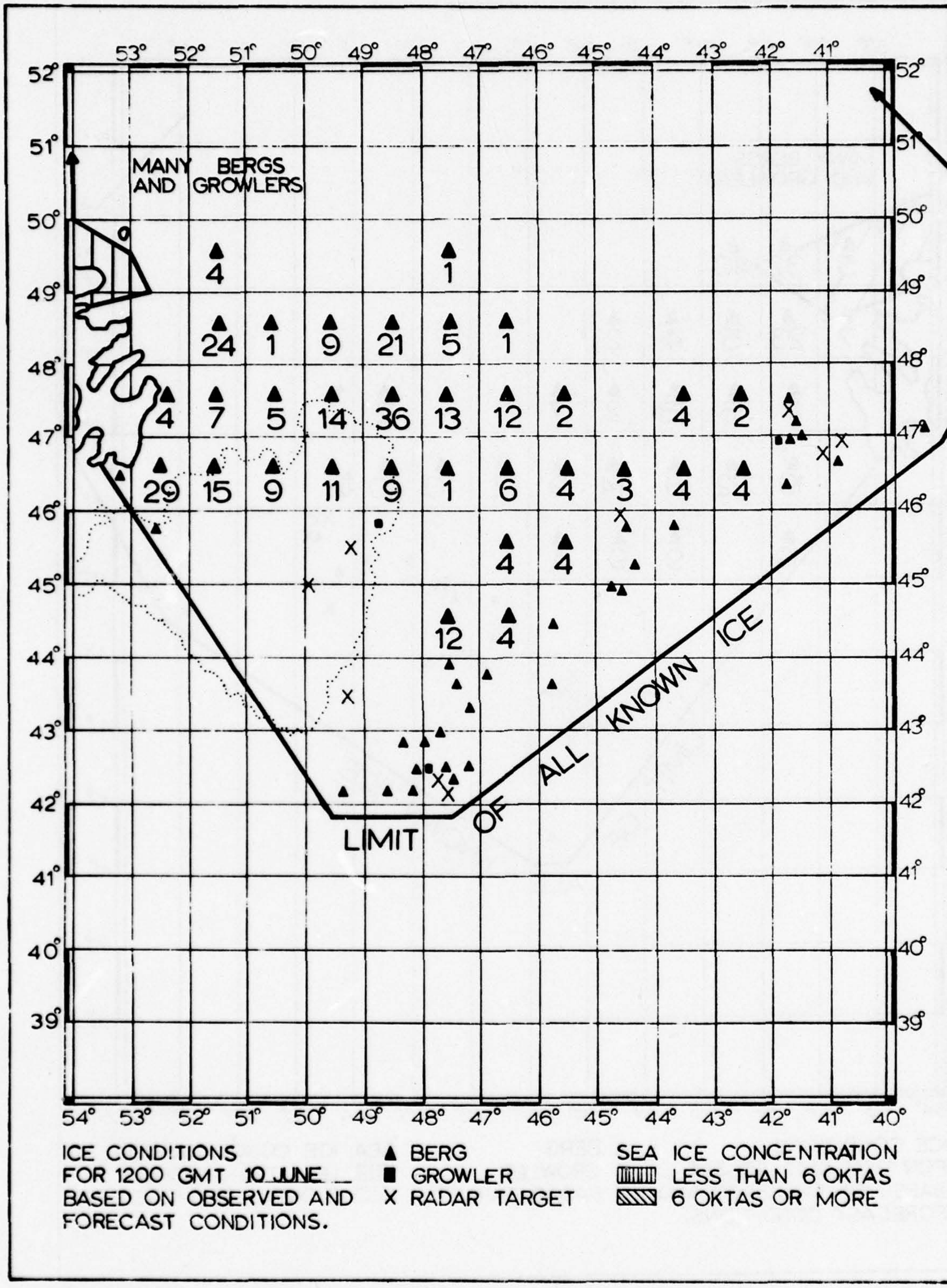

FIGURE 17.—Ice Conditions, 1200 GMT 10 June 1974.

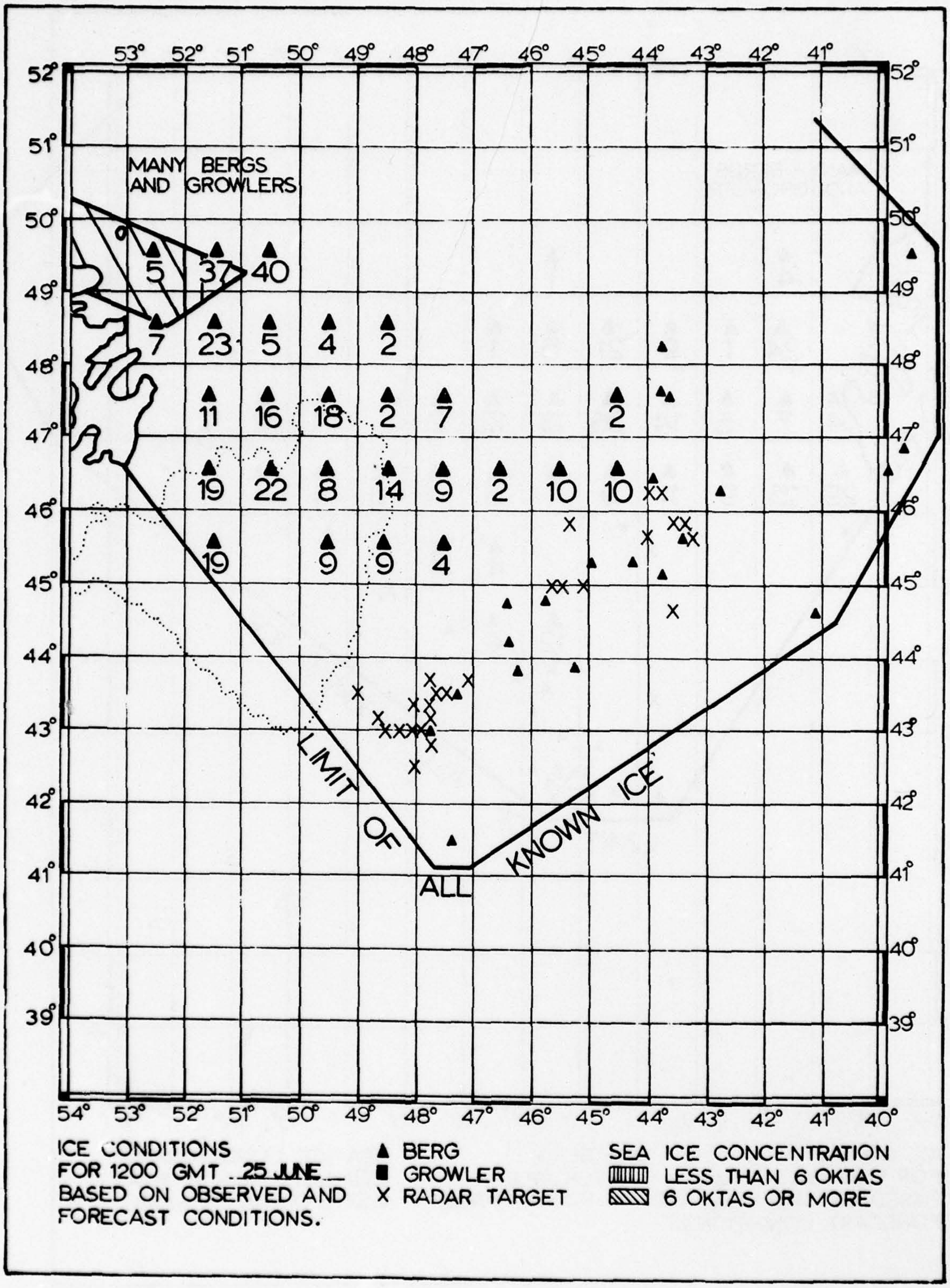

FIGURE 18.—Ice Conditions, 1200 GMT 25 June 1974.

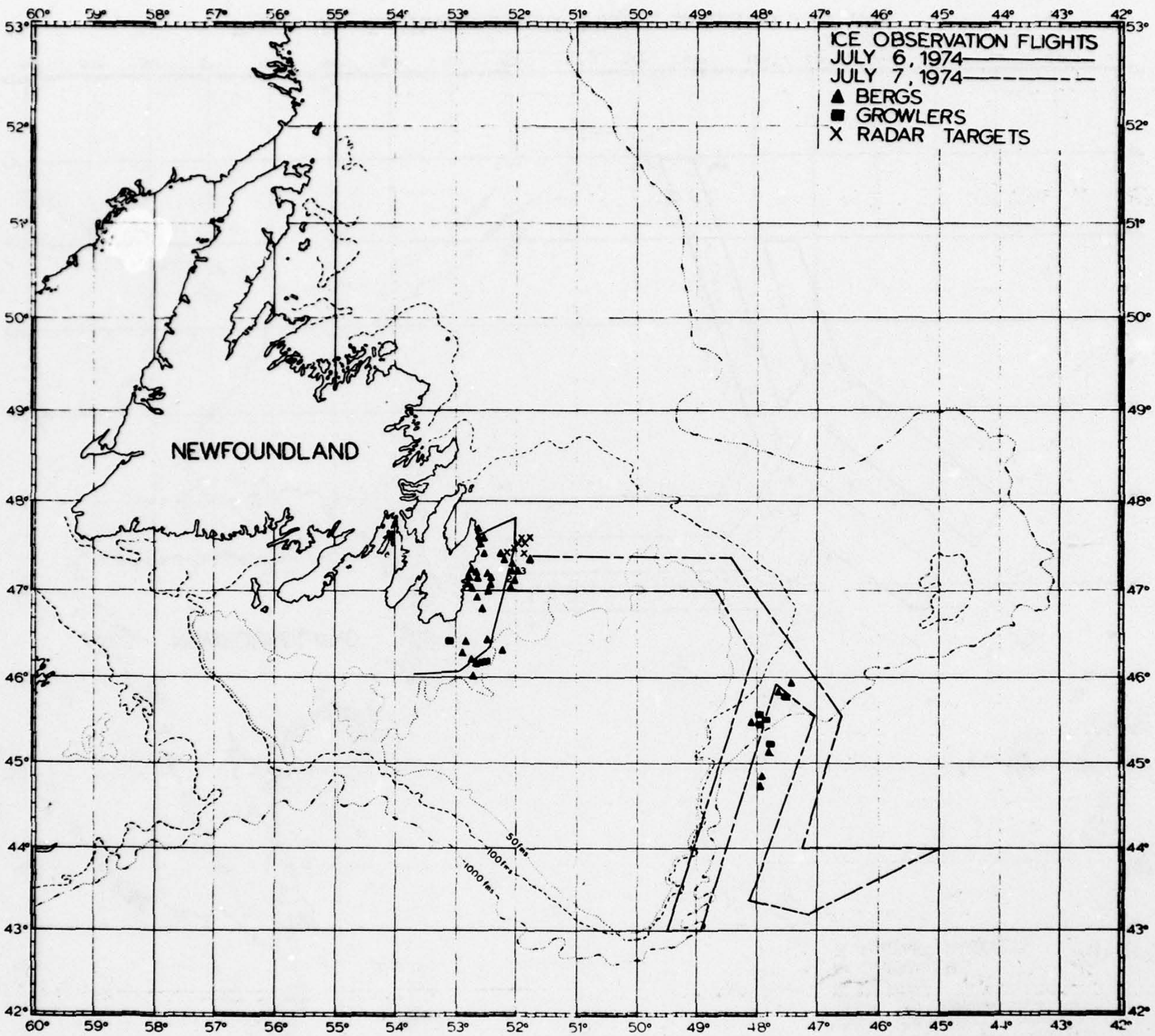

Figure 19.—Ice Reconnaissance Flights, 6 and 7 July 1974.

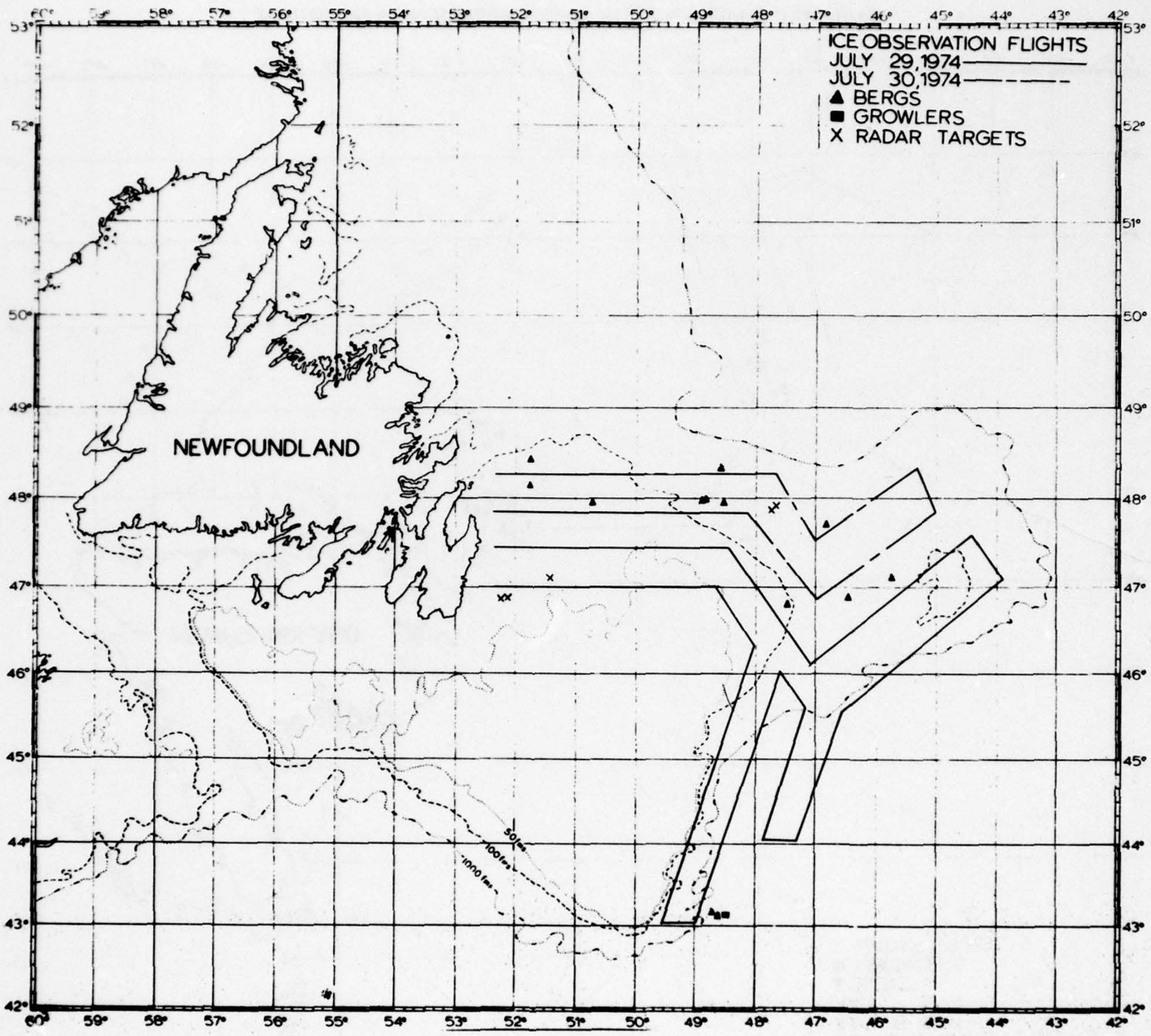

Figure 20.—Ice Reconnaissance Flights, 29 and 30 July 1974.

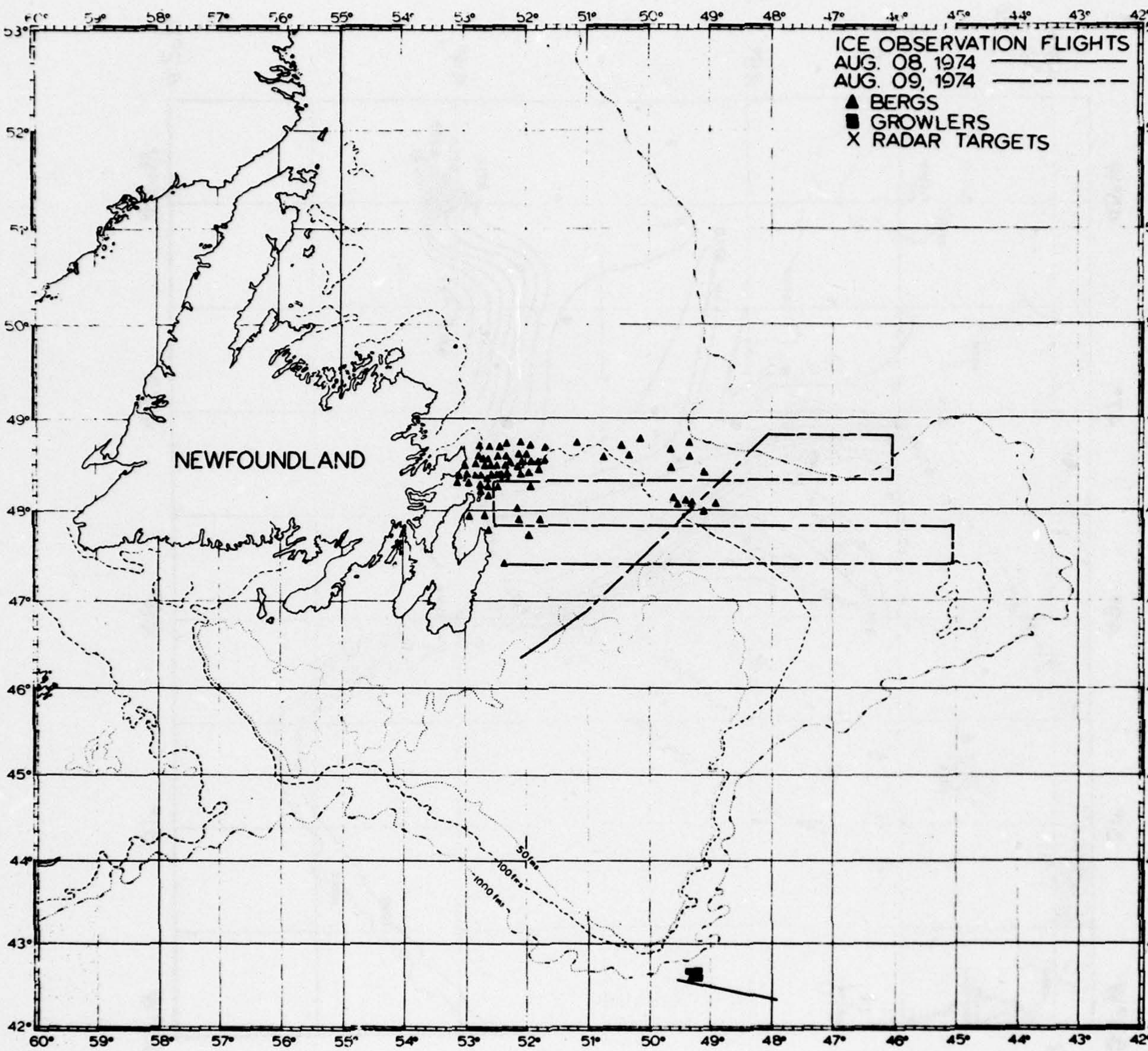

Figure 21.—Ice Reconnaissance Flights, 8 and 9 August 1974.

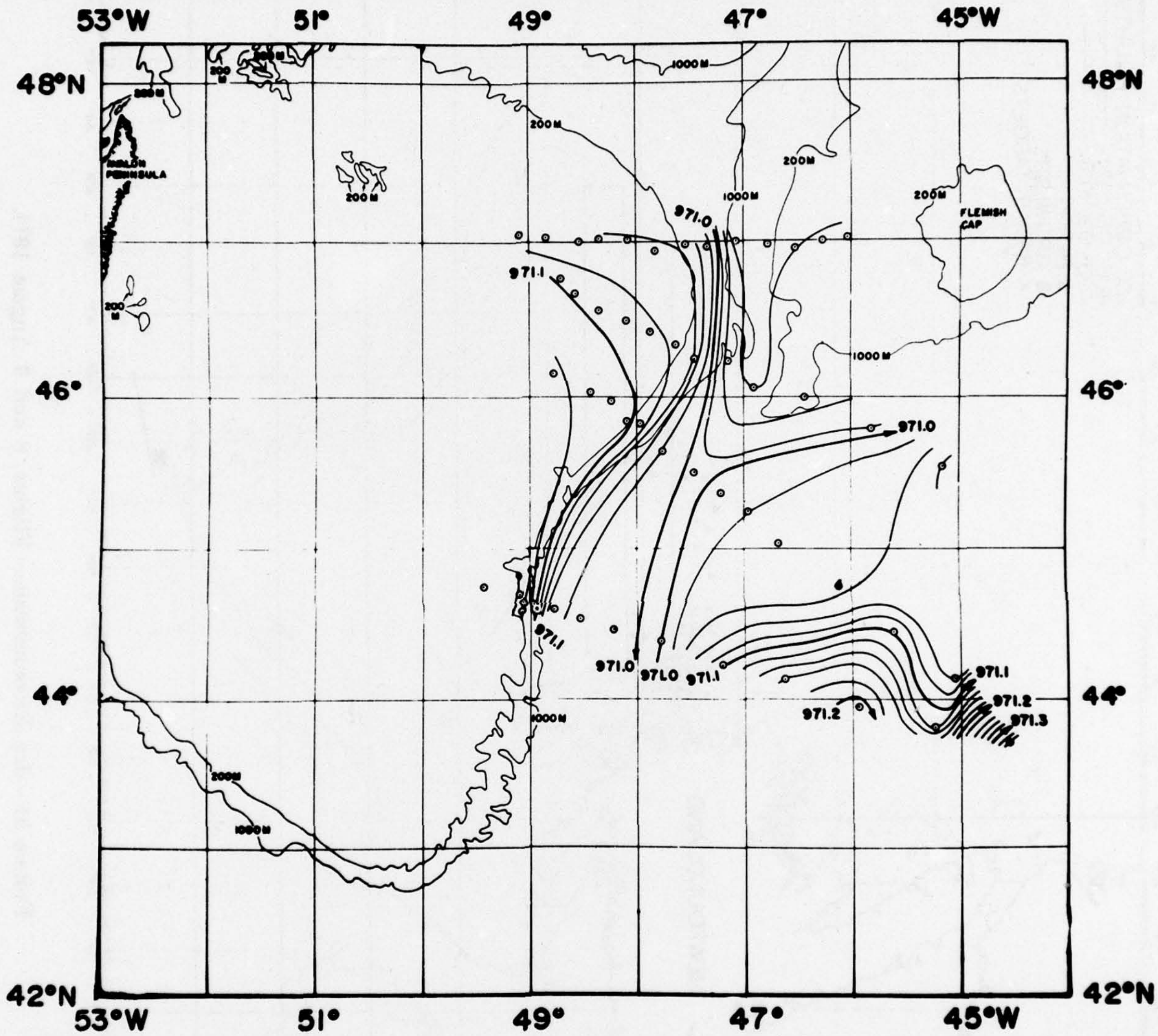

Figure 22.—Dynamic Topography of the Sea Surface with reference to the 1000 Decibar Level. (8–15 April 1974)

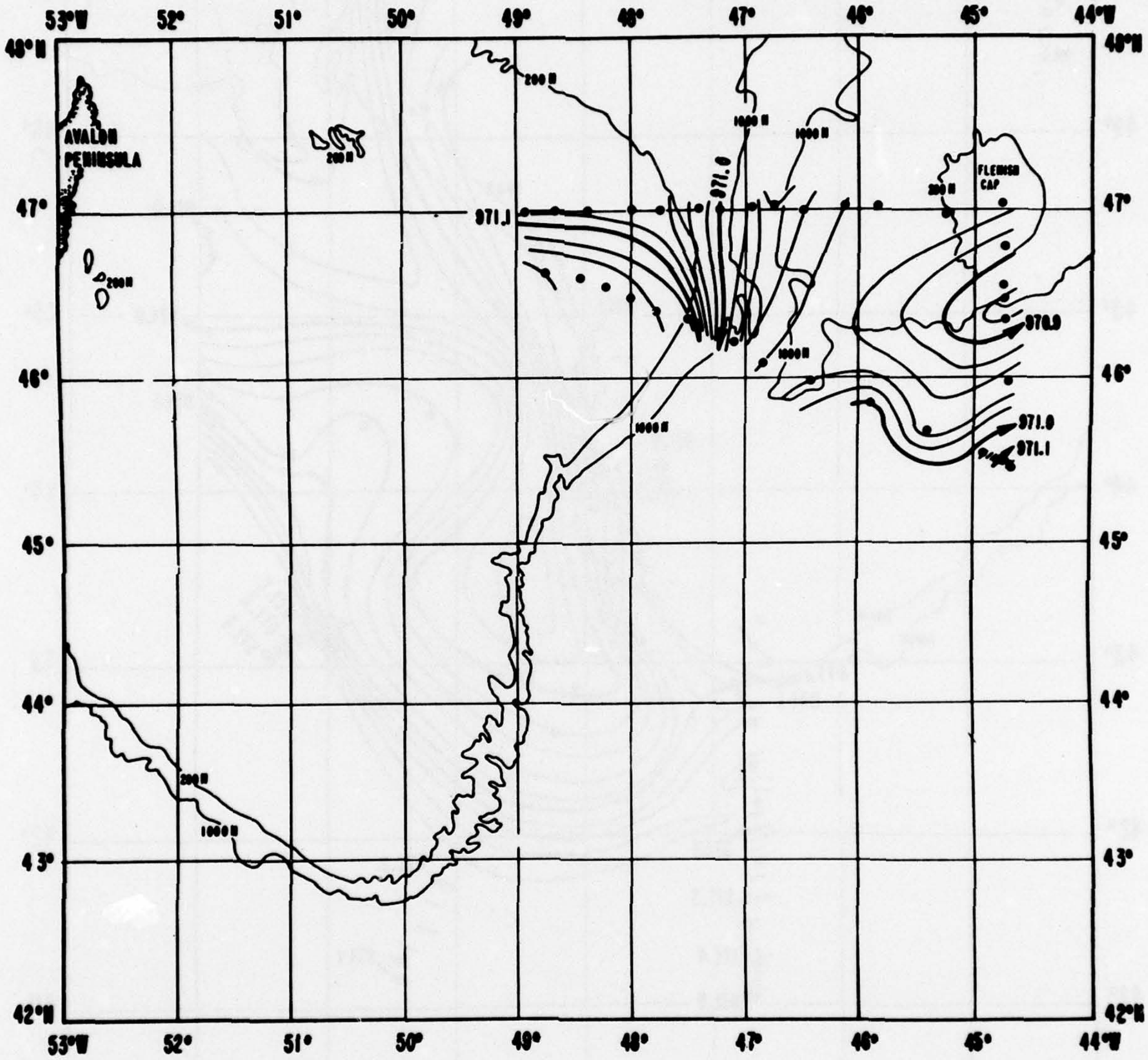

FIGURE 23.—Dynamic Topography of the Sea Surface with reference to the 1000 Decibar Level. (29 April–2 May 1974)

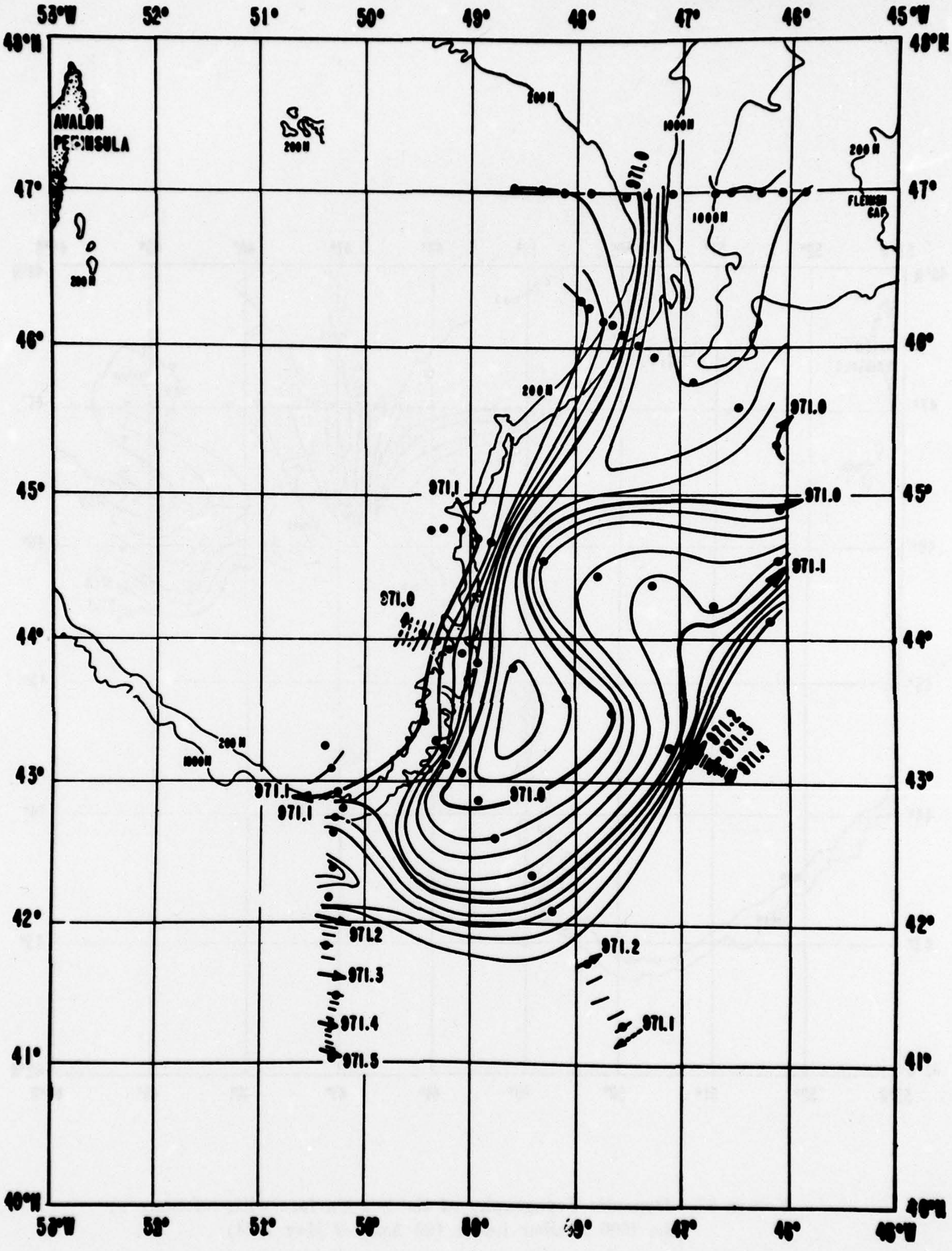

Figure 24.—Dynamic Topography of the Sea Surface with reference to the 1000 Decibar Level. (9–17 June 1974)

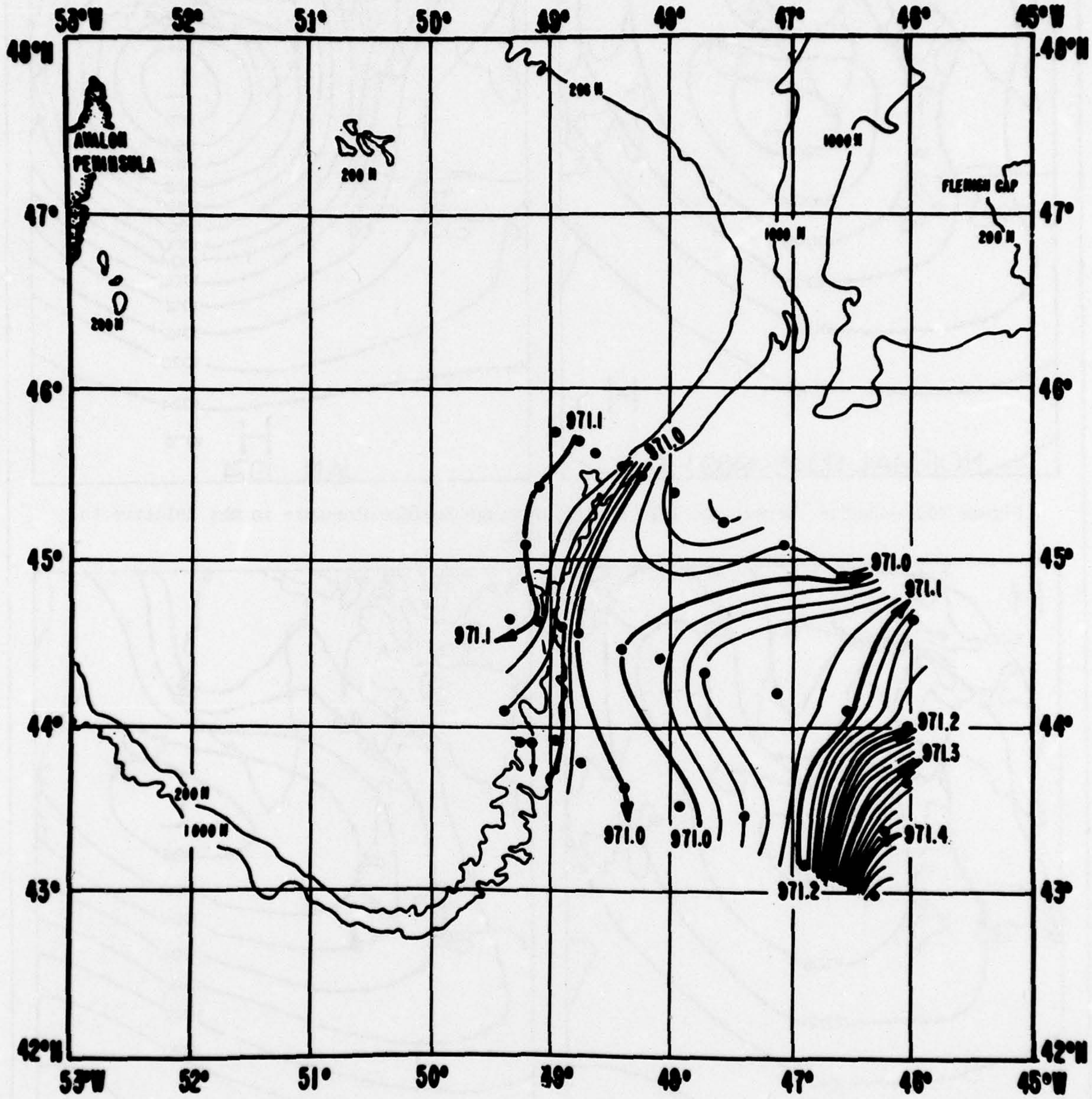

Figure 25.—Dynamic Topography of the Sea Surface with reference to the 1000 Decibar Level. (29 June–3 July 1974)

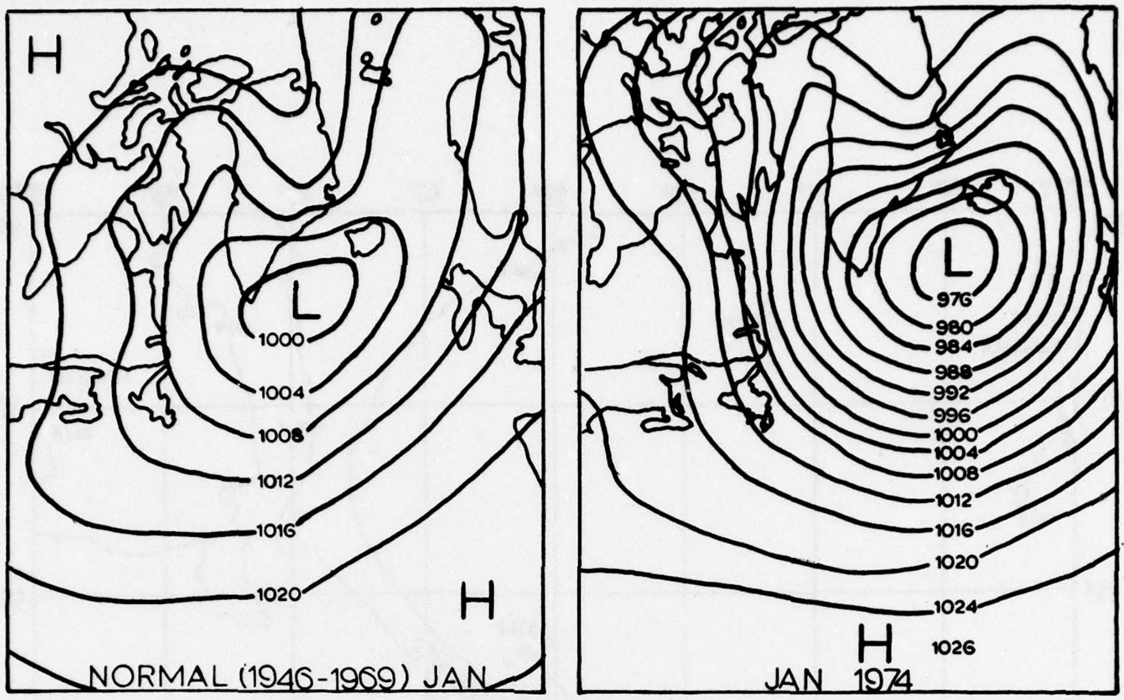

Figure 26a.—January Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

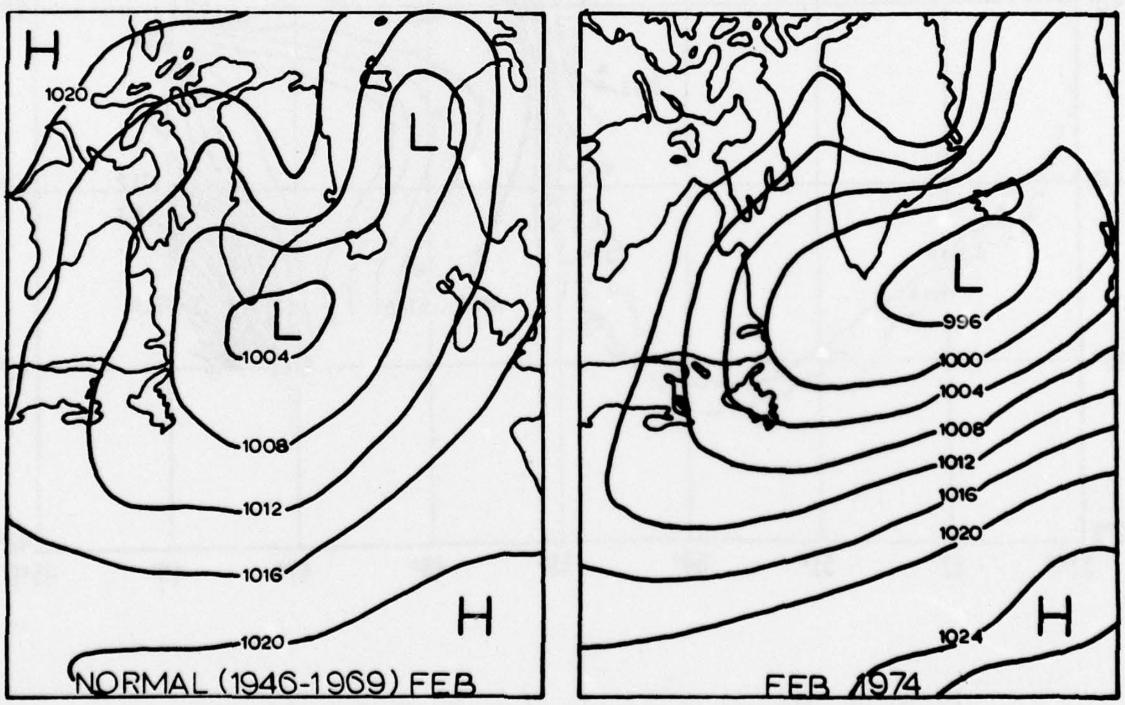

Figure 26b.—February Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

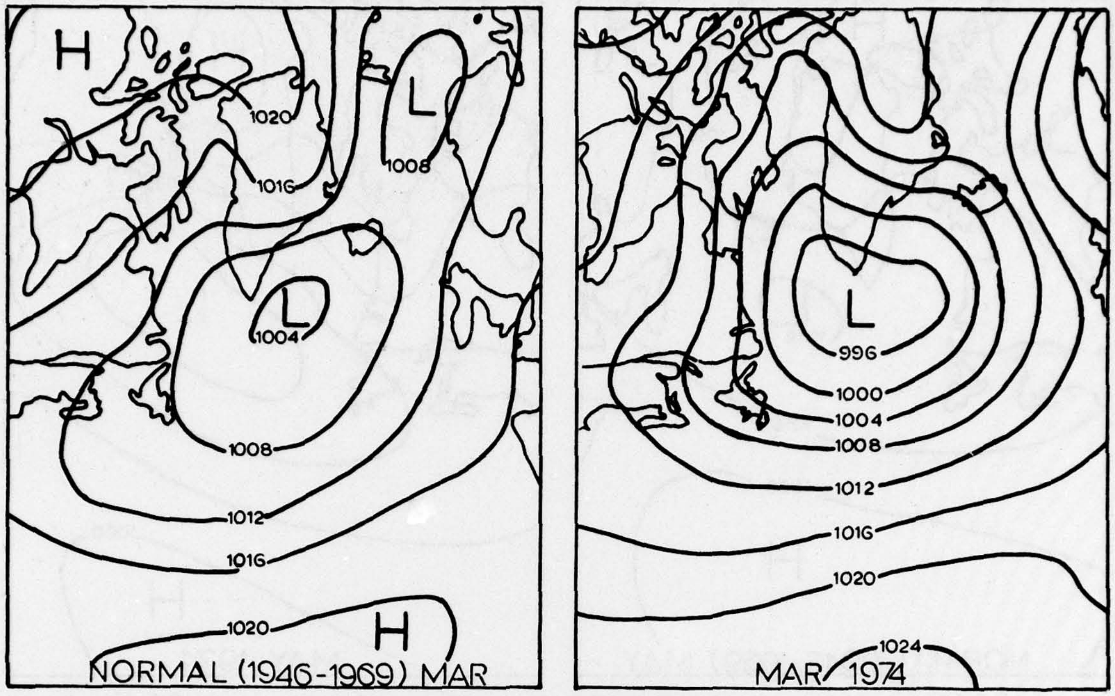

Figure 26c.—March Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

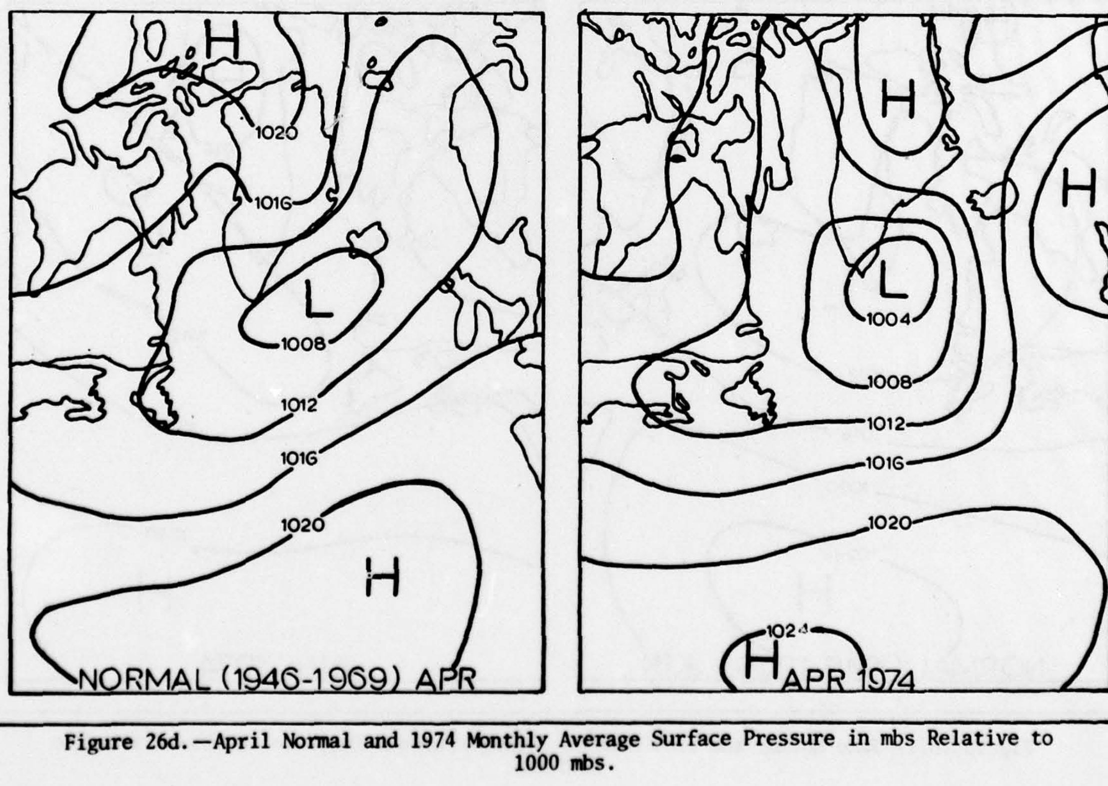

Figure 26d.—April Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

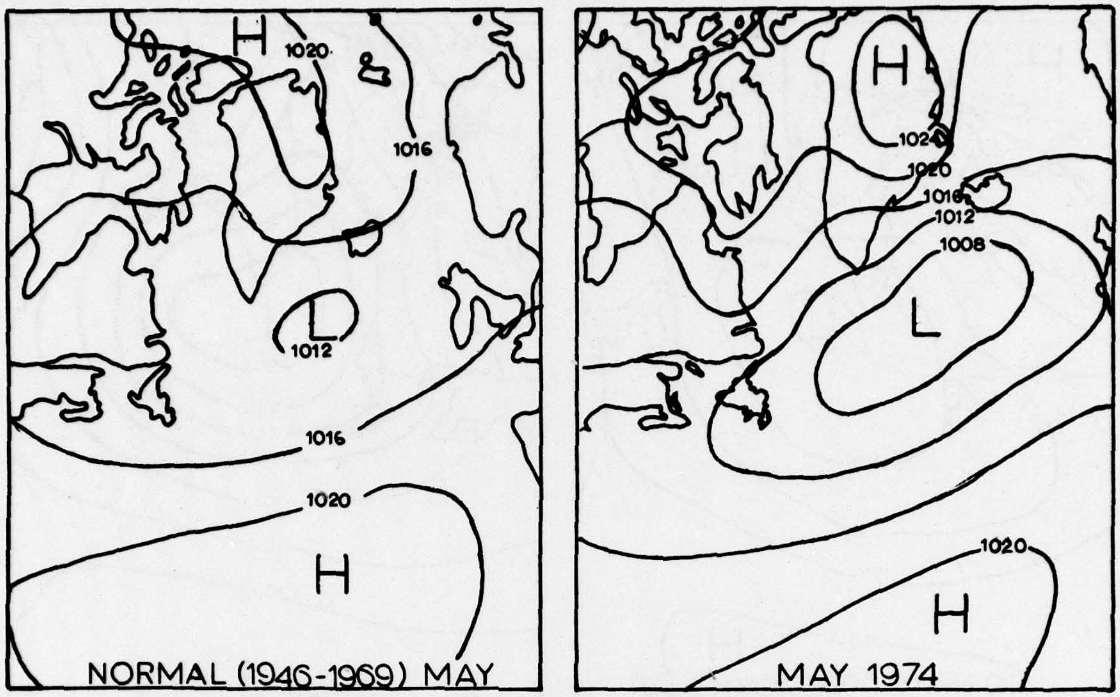

Figure 26e.—May Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

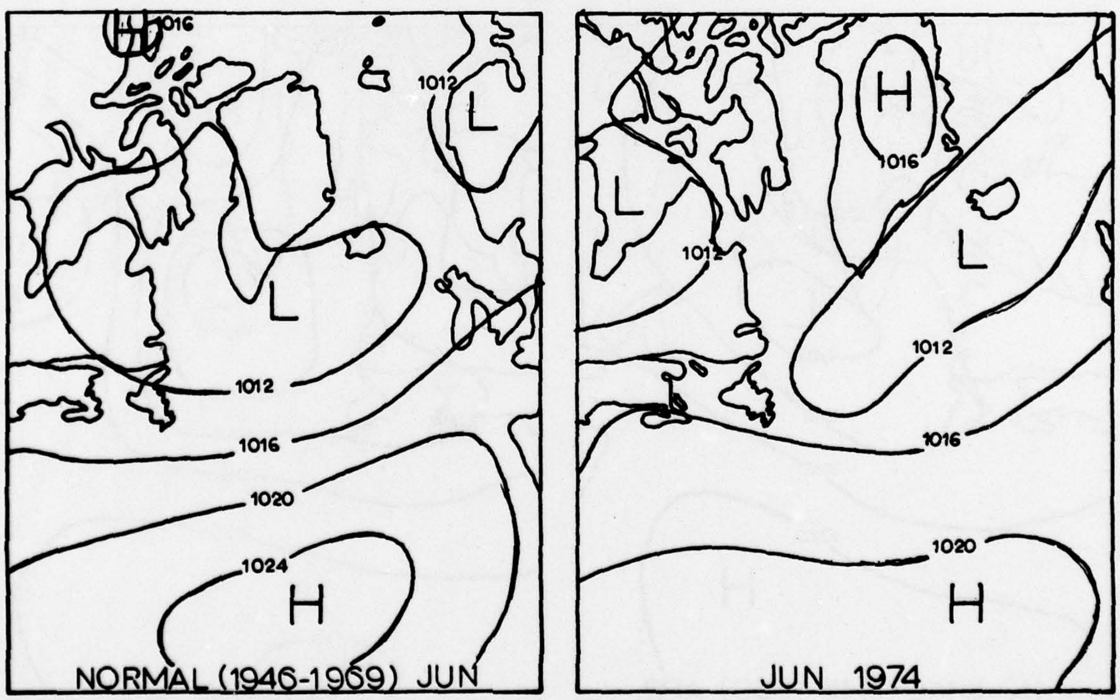

Figure 26f.—June Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

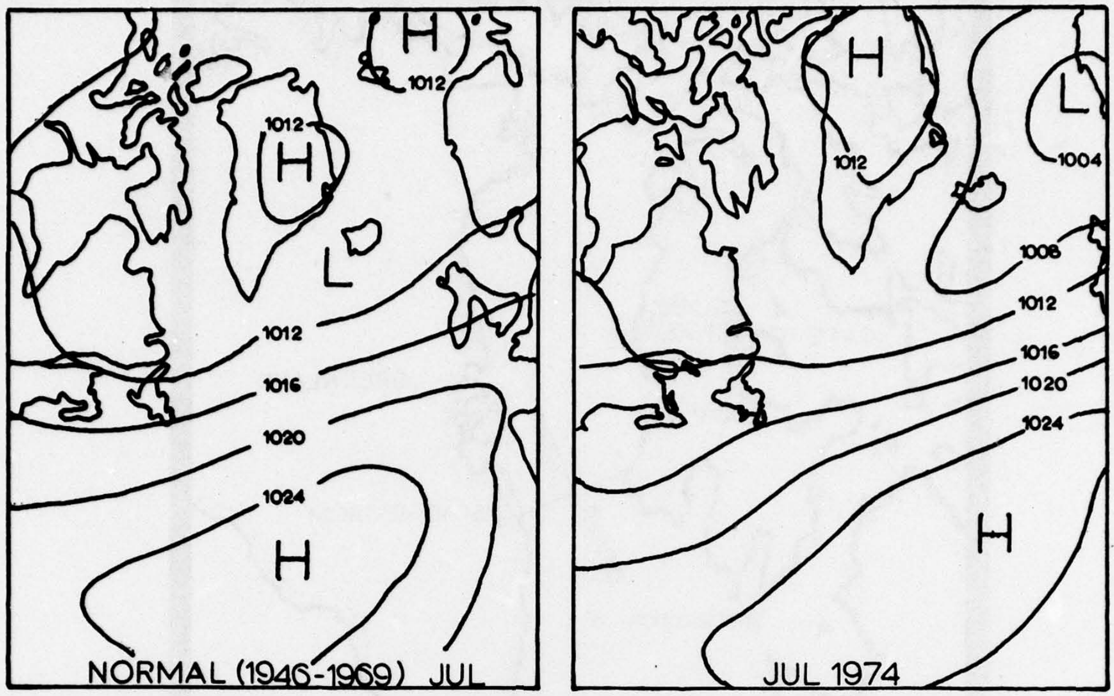

Figure 26g.—July Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

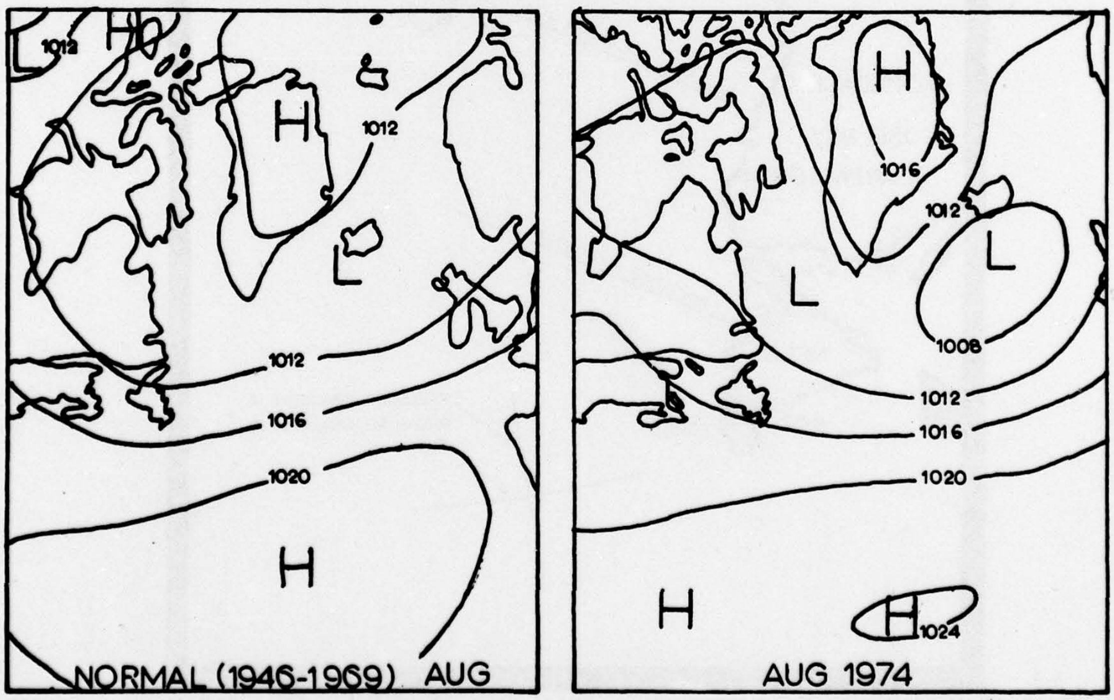

Figure 26h.—August Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs.

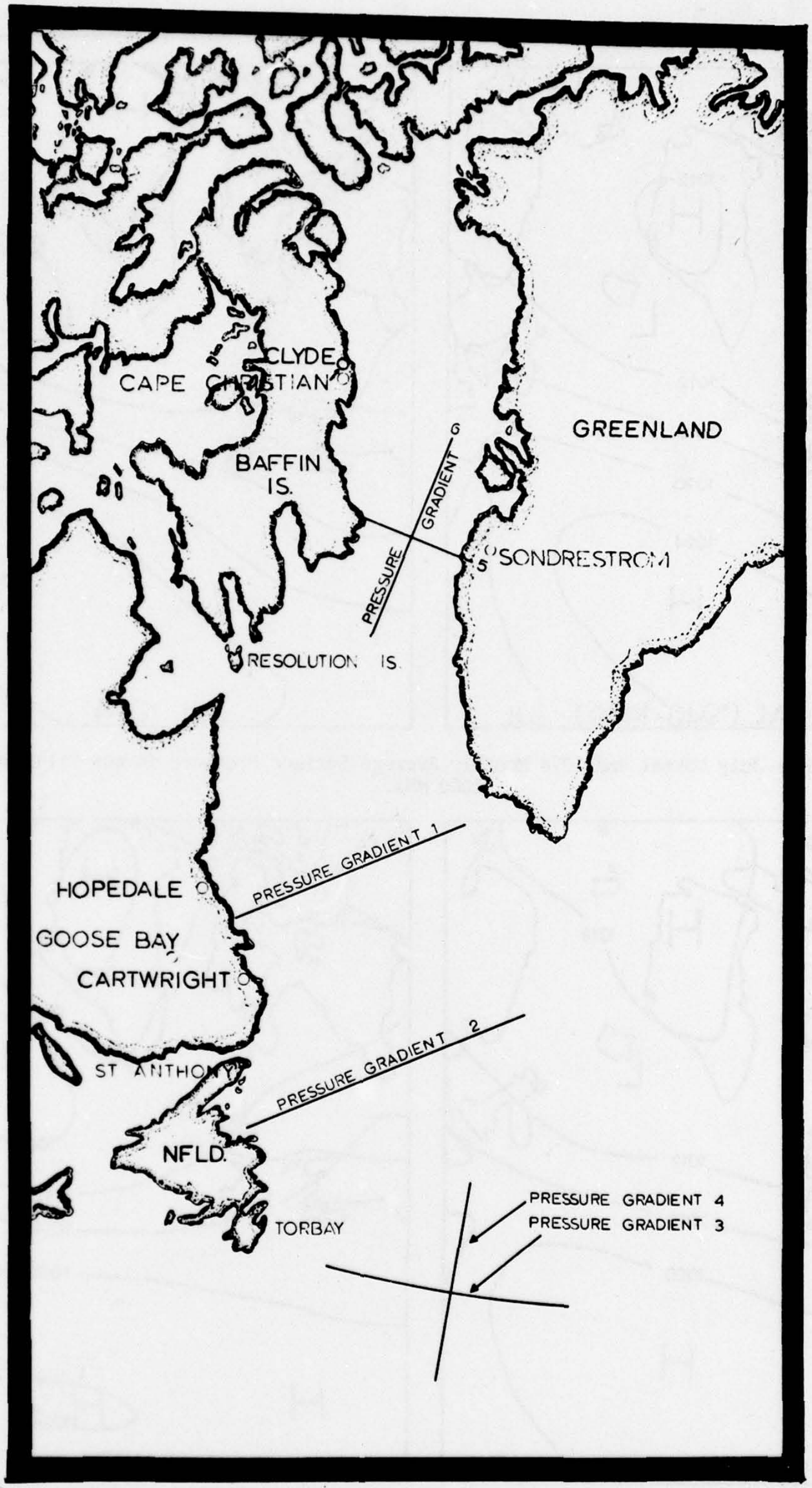

Figure 27.—Pressure Gradients Monitored by International Ice Patrol.

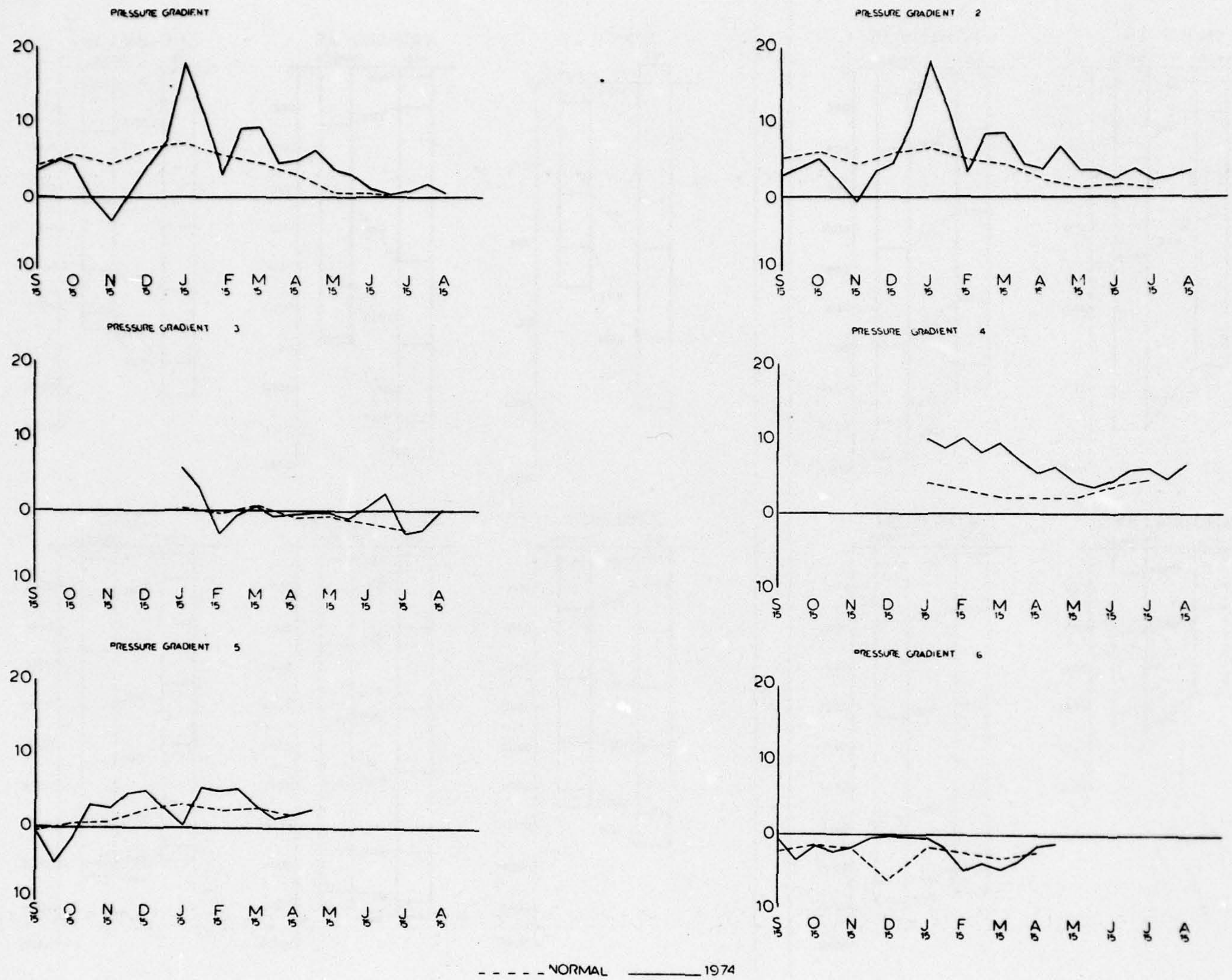

FIGURE 28.—Pressure Gradients 1–6, 1974 Season.

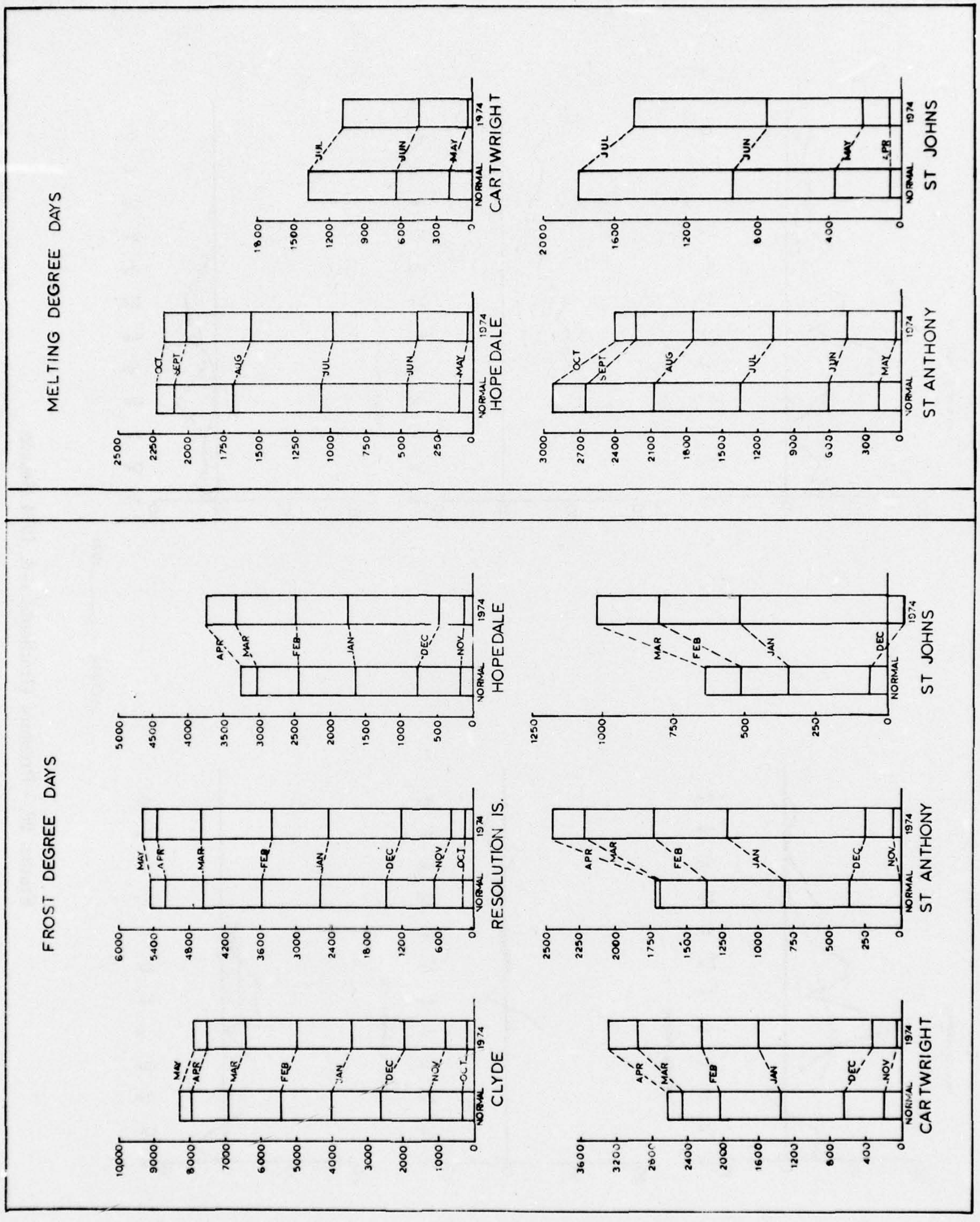

Figure 29.—Frost Degree Day and Melt Degree Day Accumulations Calculated from Monthly Mean Fahrenheit Air Temperatures.

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